LECTURE NOTES ON BUILDING CONSTRUCTION.

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BUILDING CONSTRUCTION.

SELECTION OF SITE FOR BUILDING

The following main considerations should be borne in mind while selecting building sites in the forest areas:-

Water Supply:-Good drinking water should be available throughout the year within a reasonable distance from the building site. Hence the site should preferably be near perennial streams or springs. If the source is a well it should be sunk first to ascertain the reliability of such a source, and for use during construction.

Convenient accessibility:- Site should preferably be near existing roads etc., to save additional expenses for constructing such approach roads. Such a site will reduce cost of transport of building materials to site.

Availability of building materials nearby:- As much of the heavy building materials such as timber, stone etc., should be available nearby, to save transporting cost of material.

Healthy Location:- A well drained site will be generally healthier. Avoid marshy locations. A site slightly elevated from the surround will generally be well drained. Frost holes should be avoided.

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Location (within the are the building is constructed). The site should as centrally located as possible in the area which it has to serve, so that the distance for inspection etc. may be the least possible from the site.

Aspect:- Means facing of the building. The facing should be such that in hot localities the hot afternoon sun should not beat directly into main rooms. In cold localities on the other hand, the main rooms should receive the direct rays of sun.

In hilly areas building should face down-hill.

A good natural view. There should be a good natural view seen from the front of buildings. This can be easily availed of in areas under forests.

Exposed Ridges should be avoided. During storms buildings located in such ridges have no protection and roofs etc., are liable to be blown away.

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PARTS OF THE BUILDING.

A building consists of two main parts.

(I) Foundation. This is the portion of the structure below ground level and up to plinth level.

(2) Super-structure. It is the portion above the plinth level. It consists of the following subsidiary parts:-

(a) Walls - Exterior and partition.

(b) Flooring.

(c) Roof.

(d) Others like stairs, doors, windows, chimneys etc.

F O U N D A T I O N.

The normal shape of foundation of a building is as shown in the sketch.

The main parts of such a building foundation are the following:-

(1) Concrete base. This is ordinarily the bottom-most course of the foundation. The purpose of providing this is-

(a)To bridge over small uneven-ness in the excavation of trench bed.

(b) To provide a hard bed for constructing the masonry footings.

(c) To resist any uneven settlement in different parts of foundation bed which would otherwise cause cracks in the super-structure walls.

(2) Masonry Footings. The purpose of constructing footings in the foundation is to increase the basal area of the walls gradually and economically. When the footings are constructed of bricks each has an off set of quarter length of brick and 2" to 3" in the case of stone masonry.

(3) Plinth wall. This is the wall immediately above the footings. It is meant for-

(a) To retain the basement filling on top of which is laid the flooring.

(b) To raise the floor of the building well above the ground level.

(c) To prevent moisture from entering into the basement.

The height of the plinth wall varies according to the size of the building, locality, nature of site etc.

PRINCIPAL CAUSES OF FAILURE OF FOUNDATION.

(1) Inequality of settlement. Unequal settlement in different parts of the foundation may occur due to the following causes:-

(a) Unequal bearing power of soil in different parts of the foundation. This is likely when some portions of the foundation are built over natural soil and some over made up soil such as recent fillings etc.

(b) Unequal loads transferred to the soil under different parts of the structure without taking special precautions so that there is no excessive pressure on the foundation soil under such parts as heavy columns, arch abutments etc. Under such portions the foundation should be made wider to provide sufficient area so that the intensity of pressure on the soil is restricted to its safe bearing power. If the soil has low bearing power and the structure very heavy, it may not be possible to spread out the load on sufficient area of the soil by means of footings. In such cases grillage, raft foundations etc. have to be made.

All ordinary soils except rock settle slightly when heavily loaded by the foundation. If settlement is uniform, there will be no damage to the structure but unequal settlement is liable to cause vertical cracks in the walls.

(2) Lateral escape of soil. Soft soils like peat, sand etc., are liable to be squeezed out from under heavy foundations. Such dispersal of soil is worst in the case of quick sand.

Precautions should be taken while building in such soil. As far as possible ordinary construction should be avoided on such sites. Otherwise the soil on the sides of the

foundation should be confined laterally by means of sheet-piles. Another method is to support the structure on a pile foundation.

(3) Changing moisture condition in absorbant soils. Soils like black-cotton, soft clay etc. swell up on becoming moist and shrink when dry. This causes cracks in such soils. If such cracks are present under the base of the foundation, the soil will not support the foundation uniformly. This may result in failure of the parts where there are wide cracks.

When buildings are erected on such soils, necessary precautions which are described under 'Improving bad soils in foundations', should be taken.

(4) Atmospheric Action. Some soils like soft clay become slush when saturated with water, thereby decreasing its bearing power considerably.

Foundations in such soils should be deep enough so that rain water should not easily penetrate up to the soil which supports the foundations. An additional precaution is to provide an impervious apron at ground level all around the building. This will prevent free percolation of water into the foundation soil.

(5) Forces tending to overturn. Excessive wind pressure, inclined thrust of arches, sloping roofs etc. induce an overturning tendency in walls. This may produce tensile stresses in the masonry walls, which it cannot resist safely.

The width of the foundation should be such that the resultant of the forces acting on the walls should fall within the middle one third of the base width of foundation. This will prevent tensile stresses in the walls.

(6) Sliding of the foundation soil.- If the soil on which the foundation rests is thinnly stratified, there is a likelyhood of its different strata sliding when loaded heavily. This may cause movement in the foundation soil, which may result in the failure of the foundation. This is more likely to happen in hilly areas.

One of the precautions to be taken in such cases is to construct deep retaining wall below the ground level to prevent sliding in any portion of the soil supporting the building.

COMMON SOILS IN FOUNDATIONS

Rock.-It is an excellent foundation soil which is not subject to any settlement if the bed is deep and sound. The common defect found in rock beds are deep tissues or cracks. These should be plugged with concrete if any are found under the base of the foundation. It is difficult to produce by wedging, chisseling, blasting etc., an even surface over which the building has to be constructed. Any small unevenness found in levelled bed can be made up with concrete.

(2) Gravel.-This is practically incompressible. It is not very much affected by atmospheric actions and there would be no lateral movements when ordinarily loaded. On the whole this is a good foundation soil.

(3) Clay.- All clays are subjected to expansion and contraction which produces cracks, due to variations in moisture content in the different seasons. Soft clay found near the ground surface is not a good foundation soil and as far as possible such sites should be avoided. Otherwise special precautions described later should be taken before the building is constructed on such clay.

Hard clay which is generally found in the deeper strata is a fairly reliable soil for foundations.

(4) Sand. It is a reliable foundation soil if it is kept laterally confined with the help of sheet-piles. Otherwise it is liable to be scattered away by heavy loads and sub-soil water.

(5) Black-cotton soil. The effect of changing moisture conditions in this soil is similar to clay, but is much more pronounced. It is not a reliable soil for foundation and for building on such soil, special precautionary measures would be necessary.

SAFE BEARING POWER OF SOILS.

Made up soil, black cotton, peat	..	...	½ ton/Sq.ft.
Soft clay, sand loose or wet	..	...	1 ton -do-
Stiff clay and compact loam	..	...	2 tons -do-

Red earth	..	... 3 tons/Sq.Ft.
Dry clay and compact Gravel		... 4 tons -do-
Gravel and coarse sand mixed		... 6 tons -do-
Soft Rock	..	... 5 tons -do-
Hard Rocks	..	... 5-20 tons -do-

THE DESIGN OF FOUNDATION

The important dimensions of the foundation which are to be ascertained by design are -

(1) Depth (2) Width.

Design of Depth. For designing the minimum 'depth necessary for ordinary building foundations' Rankin's Formula for minimum depth of foundations' is usually used.

The Formula is as given below

$$D = \frac{P}{W} \frac{(1-\text{Sin}\ \emptyset}{(1-\text{Sin}\ \emptyset}$$

In which P- load transferred per square foot of soil. The design will be most economic when P- is equal to the safe bearing power of the soil.

W Weight per c. ft. of soil

Ø angle of repose of soil.

While designing foundations of building it should be borne in mind that the above formula gives only the minimum depth necessary. The actual depth should be decided upon taking into account some of the Empirical rules given below:-

Design of Width. The width of foundation should be such that the load transferred by the structure to the foundation soil is under no circumstances more that the safe bearing power of the soil. For economy in design the intensity of pressure on the soil when it is loaded should be equal to the safe bearing power.

$$B = \frac{L}{B}$$

where B - width necessary for foundation

L is load per foot length of foundation

S is the safe bearing power of soil.

Some empirical rules connected with design of foundation.

(1) 2T Rule - The width of the last footing should be double the thickness of the super-structure wall. The provision of this width will ordinarily safeguard against the violation of the middle third rule.

(2) The depth of the last footing should be double that of the footings above. This is to prevent crushing of the base of masonry.

(3) The offset of concrete base beyond the edge of the last footing should be about 4" to 6".

(4) For lateral stability and to prevent easy percolation of rain water to the soil supporting the foundation no building foundations on ordinary soils should be lesser than three foot in depth.

(5) The depth of concrete base should be ascertained by design as shown below.

METHODS OF IMPROVING BAD SOILS IN FOUNDATION.

(1) Increasing the depth of foundation. The simplest method is to provide a foundation deeper than ordinary, as in deeper strata the soil is usually harder than in surface layers. The soil at such depth will not be affected easily by rain water etc., percolating into it.

In some locations where groundwater table level is high the soil in the deeper layers will moist. This method is not suitable for such localities.

(2) Proper drainage of sub-soil. Soils which are affected by sub-soil water conditions can be improved considerably by providing underground drainage channel around the various portions of the foundations.

(3) Adding sand gravel or broken stones in the foundation soil. Weak soils like peat, soft clay etc., can be improved by spreading sand, gravel or broken stones in the bed of the foundation trench. This layer is thoroughly rammed and mixed with the original soil. This improves the bearing power of the soil to some extent. But it is not quite satisfactory for heavy structures.

(4) Spreading boulders under the foundation. This method is at times adopted in soft clay and black cotton soil. A hard layer is artificially created under the foundation by spreading boulders. The trench is dug deeper by about 1' to 2' and big boulders are hand packed closely in the bed. The interspaces are filled with stone chips. The normal foundation is built above this layer.

(5) Using piles to support the structure. Poor soils can be consolidated by driving piles into the soil. If piles are driven to sufficient depth, the entire load of the structure can be borne by such groups of piles.

Piles may be of wood, concrete or steel. For ordinary foundation work piles of hard durable timber are satisfactory.

Construction of timber pile foundation. Ordinarily timber piles varying in diameter from 6" to 12" are used. If

the soil is hard an iron shoe is fixed at the lower end and a ring at the upper end. This will prevent splitting of the upper end and injury to the penetrating lower tip.

Mode of driving. Piles are driven with the help of devices called pile driver. The common types of pile drivers in use are steam pile drivers, field pile drivers and various types of improvised pile drivers. For ordinary construction work a field pile driver is by far the most suitable.

Piles are driven in the following manner.

(a) For thin light walls a single row of piles is driven along the centre of the foundation trench. The minimum spacing between adjacent piles should be $2\frac{1}{2}'$ and the maximum about 4'. A defect of this method of piling is that the row of piles may form a fulcrum about which the foundation resting on it may tilt.

(b) In multiple rows:- Piles are driven in two or more parallel rows according to the width of the foundation. The spacing between piles and rows is as mentioned above. This method is suitable when the entire load of the structure is borne by the piles.

(c) Piles may also be driven in a staggered manner. Such an arrangement is most suitable when the main purpose of pile driving is to consolidate the soil.

For carrying heavy loads all piles should be driven until they penetrate into hard soil, or until the average set of the last three blows is $\frac{1}{2}''$ or lesser. But for light walls a penetration of 10' would be sufficient.

After the piles are driven their tops are cut with the foundation bed level squared timber beams are fixed over the heads if the piles to support a timber platform on which the foundation of the building is built.

All alternative method is to lay a suitably reinforced cement concrete slab over the piles. The building foundation is constructed above.

Action of piles.-Piles act in the following ways:-

(a) By compressing the soil sideways by its penetration.

(b) By acting as a column, when its lower end rests on a hard stratum.

(c) By 'skin friction' with the soil surrounding its surface.

Piles cannot be driven in soils containing sunk boulders or other obstructions.

Safe load on piles. One of the formulae commonly used for calculating safe load on piles driven by drop-hammer is the Engineering - New formula given below:

$$\text{Safe load in lbs.} \qquad \frac{2WH}{S\ 1}$$

W weight of drop-hammer is lbs.

H is the fall of hammer in ft.

S is the average penetration of the pile in inches for the last two or three blows of the hammer.

GROUND TRACING OR SETTING OUT THE FOUNDATION

Ground tracing means marking out the line of the edges of the trench in which the foundation is built so that excavation can be made to the required dimensions.

Procedure- Draw a plan of the trench to a convenient scale and mark out the dimensions of all lines (the outer and inner edges of trench) the width of the trenches, lengths of centre lines etc., by calculating correctly and not measuring from the plan.

The site should be cleared and levelled. All the tree stumps should be removed completely. Setting out is best done with the help of centre lines of trenches, using a steel tape for measurement. First lay out one of the longer centre lines with the help of pegs and light strings, bearing in mind the orientation (facing) of the building. With respect to this line, lay out the other outermost centre lines and complete the outer figure first. The right angles between the lines should be laid out very correctly by any of the well known methods. Before proceeding further, check the diognals and

ascertain that they are equal. Then proceed to lay out the internal centre lines. Check all the diognals of any rectangle or square formed. When every thing is found to be correct, mark the lines with line on the ground. Lay out half width of trenches from the ends of centre lines and mark the edges of all trenches.

The centre lines should be transferred on some marks for later reference and check during construction. This can be done in the following ways.

Method 1. This is to be used for all permanent structures. Erect masonry pillars, 1 or $1\frac{1}{2}$ brick square with a base about 9" deep the ground level, its height being up to plinth level, in line with the centre lines of trenches and about 2' away from their outer edges. In the case of internal partition walls, there is no objection to bench marks being within the internal walls. Apply cement plaster on the top surface or inner surface of bench mark pillars and transfer the centre line on the wet plaster by pressing a string along the correct line of the centre lines.

Method II. Another method of making bench marks which can be used for temporary structures is to bury one layer of bricks blat, 9" square and lay above it another layer of similar size on edge in mortar. The top surface of this should be about 3" below ground level. A thin layer of cement plaster is placed over this and the centre line marked on this as before.

Method III: Stout pegs with nails driven above them are fixed in the ground along the centre lines of trenches.

EXCAVATION OF TRENCH.

If soils is hard enough and the trench not very deep, digging can be done without any support on the side of trench, as it goes deeper. The precaution to be taken is that no overdigging either sideways or in the depth should be done.. If any is done in depth, it should be filled with concrete and not with soil, because made up soil has very little

bearing power. The bed of the trench should be level and even. Whenever possible the levels of the different portions of the finished trench should be checked with a telescopic level. The trench excavation should be passed by a responsible person before construction is started because, shapes and sizes of the rooms etc., will depend on the dimensions of the trenches.

<u>Excavations in loose soil</u>. If the soil is loose like sand and the sides of the trenches are liable to slip down on excavating deep, it should be supported by timber boards called 'poling boards' along the sides of the excavation. The poling boards are usually about $1\frac{1}{2}$" to 2" thick and 12" broad. These boards are placed touching each other along the sides of the trench, in the case of very loose soils and about 2' to 3' apart in moderately hard soils. Across the boards walling pieces of about 2" x 3" to 4" are nailed at the interval at which the boards have to be strutted across. Ordinarily the struts are fixed at vertical intervals of 3' to 5'. The struts are tightened between the walling pieces on the opposite sides of the trench by means of wedges. The distance between struts along the length of the trench is about 5'. Additional boards can be fixed as described above as the excavation goes deeper and deeper.

LAYING THE CONCRETE BED

Wet the trench bed thoroughly to prevent it from absorbing water from concrete. Keep all materials for concrete laying ready, including the mixing platforms. Work should be started in the morning and preferably finished the same day if possible. Supply of mixed concrete should be continuous and sufficient so as not to hold up the work of laying. Concrete should be laid in layers not exceeding 6" by gently depositing it. This layer should be rammed thoroughly and the next layer if any laid before this starts setting (i.e., within 30 minutes for ordinary cement). While ramming, care should be taken to keep the concrete surface level. Final levels should preferably be checked with a levelling instruments before concrete is

allowed to set.

In case the work is carried over to the next day, the arrangement should be to continue the concrete bed in length and not in thickness. The end of the previously laid portion should be left rough. On the next day, clean and wet it thoroughly and if cement concrete is used, a cement slurry wash should be applied on the irregular end and continue laying from this portion.

Concrete should be cured for 7-10 days after laying. No construction above the base should be taken up before the concrete is very hard.

CONSTRUCTION OF MASONRY IN FOUNDATION

The footings are constructed above the concrete base. Bonding should be done carefully. Details of bonds in the footings and walls are dealt with later under 'Bonds'. After the masonry portion is constructed, it should be kept wet by spraying water on the surfaces, to prevent sudden drying up of the mortar.

FILLING OF TRENCH

After the plinth wall is constructed, the trench should be filled with earth on both sides in layers of 6" and rammed and consolidated properly.

PLINTH COURSE

The top course of the plinth wall should be a course of bricks on edge, if the wall is of brick masonry, to prevent crushing of the bricks at the junction between plinth and super-structure wall.

DAMP ROOF COURSES.

The necessity of this is to prevent moisture from the exterior creeping through walls, basement filling etc., and appearing in the interior of the building, making the inner surface damp.

Moisture enters the interior from the following main sources:-

(a) Sub-soil moisture creeping through the foundation walls and from the soil below the bed level of foundation into the basement filling and rising to the surface of flooring.

(b) By rain water dripping along the outer surfaces of walls, creeping through masonry by capillary action and appearing on inner surfaces of walls.

(c) Rain water creeping through joints of exposed upper surface of parapet walls which do not have proper coping course.

Methods of preventing dampness. The following damp proof courses will minimise or totally prevent dampness from sub-soil source.

Method I. Cover the outside surface of the plinth wall with two coats of cement plaster (1:2) each 3/8" thick. Iron filings mixed with Ammonium Chloride (to hasten oxidation of iron) if added to the plaster will increase the water tightness. There are other compounds like 'Pudlo' available in the market for increasing the water tightness of plasters. Another similar coat can be applied on the inner surface also to increase the resistance to the creeping moisture.

Method II. The plinth wall is constructed upto 1½" to 2" below the final plinth level. Paint two coats of molten bitumen or asphalt. Allow it to dry. Lay a concrete slab (1:2:4 mix) 1½" thick, on the top of the wall. When it sets two coats of molten bitumen are painted on its upper surface also. Construct the super-structure wall above this course. If the flooring is of concrete, the flooring slab should be laid as a continuation of this by joining the two slabs properly.

Method III. (Membrane Method). This method consists of introducing damp proof membranes like slate, biteminous felt vitrified stoneware, lead-sheets etc., both vertically and horizontally all around the walls so as to seal off the moisture creeping into the basement. For complete damp-proofness the membrane should be continued into the flooring if it is of concrete. The mode of building in damp proof materials is shown in the sketches.

(b) Moisture on walls. The moisture from this source can be prevented from creeping through the joints in the walls by the use of mortar of richer mixes than usual and by providing drip courses along the walls to arrest the downward flow of water along the outer surfaces of walls. Plastering of wall surfaces makes it more damp proof.

(c) Moisture from open terraces can be prevented from creeping in by providing suitable copings on tops of parapet walls and drip courses at the terrace roof level. Suitable outlets such as rain-water pipes should be fitted to drain the water clear of the walls.

Hollow or cavity walls. Such walls are constructed with a hollow space between two thin walls called 'leaves' or 'skins'. The vacant space between the two leaves serves as a very effective obstruction to the passage of any moisture through the wall. In addition it serves as an excellent insulating medium for heat and sound.

The details of its construction is described under "Masonry".

MASONRY.

Masonry is the art of arranging and bedding bricks or stones in mortar, to unite them and form a homogeneous mass of the required shape with sufficient strength to resist the stresses to which it is subjected.

Masonry can be divided into two of the following main types:-

(a) Brick masonry- It is made of bricks which are manufactured artificially.

(b) Stone masonry- This is constructed of stones which occur in nature in the form of rocks.

In addition to the above two types, hollow blocks made of burnt clay or a mix of cement sand etc., are also used for the construction of walls of ordinary residential buildings. Such walls are very light and they have good insulating quality. Due to their lightness, the foundations of such walls are cheaper than that of ordinary walls of buildings.

BRICK MASONRY.

Definitions of technical terms.

Course is the name of a row of bricks between two adjacent bed or horizontal joints.

Bed Joints. These are the horizontal mortar joints normal to the pressure.

Perpends. are the vertical joints between bricks. For good bonding they should be in line in alternate courses.

Stretcher is a brick laid with its length along the face of the wall or parallel to it.

Harder is a brick laid with its length perpendicular to the face of the wall.

Lap is the horizontal distance between the adjacent vertical joints in the adjacent courses.

In brick walling the minimum lap should be equal to ¼ length of brick.

Quoins are the orners of the walls.

The term may apply to the ends of walls if there is no junction at the end of a wall, or to the junctions at the end of two walls.

Quoin Headers are the headers placed at the quoins of walls.

Queen Closer. Is a brick of the same length and depth as ordinary bricks, but with half the width of normal bricks.

They are generally made by cutting a brick into two along the length. These are placed immediately after the quoin header, to obtain the necessary lap.

King Closer. Is a portion of a brick of which one of the long faces of the ordinary brick is cut, so that only half the stretcher and header faces of the brick remains.

Bevelled Closer. Is a portion of a brick of which the full stretcher face is cut slanting.

Frog. Is the indentation formed in the middle of the bedding surfaces of the bricks to provide a key to the mortar.

Bond. Is the name given to any arrangement of bricks in which no vertical joint of a course is in line with the vertical joints of the course above or below it, but having a minimum lap of ¼ brick length.

Mortar. is the Matrix or binding material used in bed and vertical joints of masonry.

Bat. is a brick broken along its width. Depending upon its length compared to that of full bricks they are called half-bats three quarter bats etc.

Bevelled Bat. Is a bat in which the header face of a brick is cut slanting.

Splay Stretcher. Is a brick in which one of its bigger surfaces is bevelled for the entire length of the brick.

Splay Header. When the bevelling of top surface is done along the width of the brick, it is called a splay head.

Splay Headers and stretchers are used for the construction of drip courses, string-courses, copings etc.

B O N D S.

Types of Bonds. The following are the common types of bonds used in masonry.

(1) English Bond.

(2) Flemish Bond.

(3) Stretcher bond.

(4) Header Bond.

(1) English Bond. This method of bonding consists of alternate courses of headers and stretchers. A queen closer is introduced immediately after the quoin-header in every header course to obtain the necessary lap. This is the most commonly used bond for brick walling.

(2) Flemish Bond. It consists of headers and stretchers arranged alternately in the same course. Queen closers are placed immediately after the quoin header.

There are two types of flemish bonds as given below.

(a) Single Flemish Bond. When the outside face only of the wall has the appearance of Flemish bond, and the interior face that of English bond, it is called Single Flemish bond.

This type is used when the interior of the wall is finished with plaster as is the case with most residential buildings, and the exterior is pointed.

(b) Double Flemish bond. When both faces of the wall have the appearance of Flemish bond such an arrangement is called Double Flemish bond.

Flemish bonds are used for the sake of its better appearance where the outside of the wall is finished by fine pointing. It is alsoused in heavy Ashlar stone masonry.

(3) Stretcher Bond. This consists of a series of stretchers laid in successive courses. A half brick bat is introduced in alternate courses at the ends of walls to obtain the required lap.

It is usually used for half brick thick walls like compound walls panel walls, thin parapet walls, screen walls, partition walls and cavity walls.

(4) Header Bond. This consists entirely of header courses. It is not used in the construction of whole walls, but for turning rounded junctions of walls as well as for the construction of footings, corbelled courses and cornices.

(1) Detached Pillars. These have to be constructed for supporting the loads of arcades, verandh roofs etc.

The method of arrangement of bricks for square pillars in English and Flemish bonds are illustrated by sketches. If the piers and abutments of arcades are rectangular in section the normal methods of bonding as in the construction of walls are adopted.

(2) Attached Pillars or Pilasters. Thin walls strengthened by thicker pillars called pilasters, bonded into them at intervals of about 6' to 10' are at times constructed to strengthen walls of buildings and for economy in masonry. The load of roofs is transferred to pillars by supporting the trusses directly over them and thus relieving the thinner portions of the wall between the pillars of the roof load. The thicker section of masonry of the pillars is in some cases symmetrical with respect to the wall and in other cases the additional thickness of the pillars project either inward or outwards from the face of the wall.

Rules to be followed for good bonding. The following are some of the rules to be followed to obtain good bonding in walls.

(1) Arrangement of bricks should be uniform throughout the wall.

(2) As few bats as possible should be used.

(3) The vertical joints in alternate courses should be vertical and in line both in external and internal faces.

(4) There should be a lap of quarter length of brick between vertical joints in successive courses.

(5) Dimensions of brick should be such that when bedded, length should be equal to twice width plus one mortar joint.

(6) All courses should be truely horizontal and mortar joints of uniform thickndss.

(7) When standard bricks are used there should be four brick courses in a foot height of wall.

(8) All the bricks should be properly soaked in water before they are used in construction so that they may not absorb water from the mortar.

CONSTRUCTION OF WALLS

The usual method of constructing new walls is to erect the corners or junctions to a height of 2' to 3', keeping the ends of the construction racked, as shown in the sketch. The intermediate portions between the quions is then taken up. This is done by stretching a string (usually called 'line') between the top surfaces of corresponding bricks in the two racked quions opposite to each other. The level of the course of bricks then laid should correspond to that of the string. Before the bricks in each course are laid, mortar is spread evenly in the bed joint and each brick pressed into the mortar in its correct position, after the vertical face touching the adjacent bricks is coated with a thin layer of mortar. The horizontality of the bricks in each course is checked frequently with a spirit level and 'stock'. The vertical joint should be completely filled up to the top by cutting in fresh mortar with the edge of the trowel.

The following precautions should be taken during the construction of walls.

(1) No part of the wall should be raised more than 3' in height in one day.

(2) Bricks should be thoroughly soaked in water for about 12 hours before laying in the wall.

(3) All courses should be truely level.

(4) Unnecessary use of bats should be avoided.

(5) The heights of walls in different portions of the building should be ascertained correctly from the drawings and their

construction terminated at the required heights, and the tops shaped as specified.

(6) Special attention should be paid to the openings of doors, windows, wall cup-boards etc. The frames of doors etc., should be built into the walls at the correct level in the required positions.

(7) All additional fixtures which have to be embedded in walls, like drainage and water pipes, concrete or other templets, iron bed-plates, bolts, door-stops etc., should be fixed at the appropriate stage of construction. Raking out finished portions of walls for such purposes should be avoided.

Method of bonding two walls.

Toothing in courses. Any portion of wall to which a new wall is to be bonded later should be left toothed. Toothing in such cases consists of leaving the headers along the face of the wall projecting $2\frac{1}{4}$" beyond the stretcher course, so that the bricks of the wall constructed later can be bonded into these cavities.

When an old wall is to be toothed for bonding a new wall, toothing is done in the following ways. This toothing is sometimes turned chase.

(a) Cavities half brick deep and two to three courses in height are cut. The next two or three courses are left as they are, and the next two or three courses cut inwards as mentioned before, and so on.

(b) An alternative method is to cut half brick deep cavity in one course and leave the next two courses in tact. This process is continued all along the height of the wall. The bond obtained by this method is weaker.

Bonding a new and old wall. The old wall is toothed as described above the cavities cleaned, and the wall wetted

thoroughly. The bricks of the new wall are bonded with those of old wall with rich cement mortar (1 : 2 mix.).

Projecting Courses. Are the courses projecting beyond the face of walls. Examples of this are given below:

(1) Footings. This is described already under foundation.

(2) Corbelled Courses. These are projecting courses built for supporting wall plates, ends of joists, moulded cornices drip courses, sill courses etc.

Corbelled Courses for supporting wall plates. The top width of such corbelled courses should never exceed the length of a brick, as such a construction to support wall plates etc., causes eccentric stresses in the masonry. Hence heavy girders or joists of flat roofs and floors should not be supported in this manner. It is suitable only for supporting upper end of lean-to roofs or similar light loads.

Each course should project beyond the course below by 1/8th brick length. The top most course should consist of two brick courses. All projecting courses should preferably consist of header courses.

Another method which is suitable for supporting heavy joists of floors in double or multi-storied buildings, where the walls are of different thicknesses in the different storeys, is to provide an offset at the joist level at the junction of the walls of different thicknesses and fix the wall plate in the offset thus obtained.

Cornices. Projecting courses of bricks are constructed to provide a key to themortar and plaster which is moulded to artistic shapes/ to form the cornice. One to four courses may be constructed according to the size (width and depth) of cornice.

Cornices made on the interior faces of walls is meant only for the sake of appearance. Whereas those made on the

exterior exposed surfaces are meant as drip courses or to provide horizontal divisions in exterior walls so as to enhance its appearance.

<u>Drip courses</u>. These are constructed on the exposed faces of the exterior walls, to intercept and throw out the water dripping down the wall face. They are projecting courses built with bricks brought to the required shape by rubbing, or with moulded plaster. At times they are made of a single course of stone cut to the required shape. Such cut-stone courses need not be of the same width as the thickness of the wall and may tail in only about 4½" to 9" depending on the thickness of wall and width of the course.

The top of the drip course has a sloping surface which is called "Weathering". A semi-circular groove is cut along its under surface to arrest any water creeping across it. This groove is usually called 'Throating'.

<u>Sill Course</u>. It is a projecting course build immediately below the sill of windows. A sill course of bricks should be made thoroughly impervious by plastering its tops with rich cement plaster. Sills of windows should terminate in a drip course. An alternative method is to construct the sill course of concrete. Sill courses made of stone which are more expensive are used for ornamentation.

<u>String Courses or Belt Courses</u>. These are courses of bricks introduced at intervals in stone walls or courses of cut stones in brick walls.

In the case of stone rubble walls such string courses are made at intervals of 4' to 5' along the height of the wall. These are 3 to 4 courses deep. They are meant mainly for strengthening the rubble wall and also fhr the sake of appearance.

<u>Jambs</u>. Jambs are the vertical sides or faces of the door and window openings in walls. The term is often used for

the sides of other openings like cup-boards etc.

The common types of jambs are described below:

(1) Plane jamb. This is the type that is most commonly used. In this the faces of the opening are perpendicular to that of the wall. The defect of this type is that display of the opened door is lesser.

(2) Splayed jamb. In this the face of the openings inclined at an angle of about 60 to the face of the wall. The display of the door when opened will be more in this case than in the previous type.

(3) Rebated jamb. The vertical sides of this type is in more than one plane. The way in which the frame of the door is fixed in such a jamb is shown in the sketch.

STONE -- MASONRY

Stone-masonry is constructed of stones obtained from natural rocks. This type is used extensively in forests where good bricks are often not available. Depending upon the shapes of stones used and the mode of construction stone masonry is classified as given below.

(1) Random rubble uncoursed-dry or in mortar.
(2) Random rubble coursed.
(3) Squared or snecked rubble uncoursed.
(4) Squared or snecked rubble coursed.
(5) Regular coursed rubble.
(6) Block in course.
(7) Ashlar.

Random rubble uncoursed.

The stones used are of different sizes and shapes, but, as far as possible approximately similar sizes should be used. Smaller pieces called 'spalls' are used only to pack unavoidable avoids. The larger stones should be used at

the bottom of the walls. Acute tailing projections in the stones are knocked down with hammer before laying.

The method of construction is to lay the face stones of both faces of the walls carefully to a height of 6" to 9" selecting the stones so that adjacent stones fit near each other in best possible manner. The hearting is then laid selecting the adjacent stones similarily. The interspaces are filled with spalls. Long continuous vertical joints should be avoided.

Bond stones. Stones of length equal to thickness of wall, width and height two to three times that of average stones, are introduced at intervals of 3' to 5' (one per square yard is a usual rule followed in building walls) to strengthen the construction. The overall strength of the wall depends mainly on interlocking of stones and strength of mortar.

If this type of masonry is used in buildings, quoins, jambs, sills of doors and windows, arches etc. should be constructed of bricks or squared stones and random rubble portion toothed with it.

Exposed tops of rubble walls should be covered with copings built of squared stones or concrete slabs.

Uses. This type of masonry is used for buildings, compound walls, retaining walls etc.

Dry random rubble masonry should be used only in unimportant retaining walls upto about 5' height.

Random rubble coursed

Stones used are similar to the previous type. But the method of construction is slightly different. Courses are levelled at 9"-15", or 12"-18" height, depending on quality of stones by laying suitable sized stones on the top of course, filling slight depressions with mortar and finally levelling up with mortar before the next course is laid. No course should be deeper than the course below. Bigger

stones should be used in the bottom courses.

Note. A mixed type of masonry with random rubble exterior and brick interior may be used for buildings. The inside brick portion of such a wall should be toothed three courses high, 4½" deep, and next four courses 9" deep and so on. The exterior rubble portion of the wall is keyed into the toothing thus formed in the brick wall.

Square rubble uncoursed or snecked rubble

It is used where stratified stones which can be easily split along planes of cleanage is available. It is stronger than random rubble. If other types of stones which are more difficult to dress are used, faces are roughly dressed with hammer to obtain horizontal and vertical joints.

Stones are not in course but the joints are horizontal and vertical. There is a tendency to obtain long vertical joints. Hence no stone should be deeper than 8" and smaller stones called 'snecks' are introduced in hollows formed. For good work not more than side faces of four stones should form a continuous vertical joint. Through stones are introduced at intervals as mentioned previously. Joints should be 1/8" thick when fine dressed stones are used and up to 1/4" when the dressing is irregular.

Square rubble coursed

The construction is similar to that of squared rubble uncoursed, except that courses are levelled off at 12" to 18" interval in height. Vertical joints may be continuous upto two stone height. The coursing helps to avoid long vertical joints.

Regular coursed rubble or block in course or rough Ashlar

Squared stones are used in this type. Stones in the same course have the same height. Courses vary in height from 4" to 9". No course should be greater in height than

the one below. Joints should not be more than 1/4" thick. Stones should not be lesser than ½ c.ft. in size for walls under 1½' thickness and 3/4 c.ft. if over. Length and width of all face stones should be more than their height. The length should be a minimum of 1½ times the height. One third of the face stones should tail in a length of twice the height. Through stones or bond stones should be introduced at 5' spacing both vertically and horizontally. Upto 2' thickness of wall, single stones should be used as bond stones. In walls above 2' thickness two or three stones with a lap of 6" along the length can be used. Stones in the quoins should be of the same height as the corresponding course, and they should be all headers.

In superior work where great strength is required as in the case of bridge masonry, the whole wall should be of roughly squared stones. But in inferior work the hearting may be filled with rubble of size not less than 6" in any direction.

Ashlar

This is the most expensive and strongest type of stone masonry. The strength depends on the following:-

(1) Size of blocks used.

(2) Accuracy of dressing.

(3) Mode of bonding.

(4) Strength of stones used.

A good rule for the relative dimensions of stones to be used is, breadth not less than the depth and length not less than three times thickness.

The main types of Ashlar masonry are the following:-

(1) Regular Ashlar. In this the courses are all of equal height.

(2) Irregular Ashlar. The courses of this type of Ashlar

vary in height from 11" to 18". As a rule for masonry which has to bear very heavy loads the stones should be bigger in size rather than smaller.

Other specifications. Outer faces of stones should be smooth or rock faced with drafted margins about 1½" wide.

Vertical joints should be broken and should not be more than 1/4" in thickness, and finer, if well dressed stones are used.

If first class work stones should be of same length and width so that the vertical joints come in the same line in alternate courses.

The bond followed is usually Flemish. For the sake of strength in walls, upto 2½' thickness of walls, headers should have a length equal to the thickness of walls.

ARCHES

An arch is an arrangement of bricks or stones mutually supporting each other, built in the form of a curve or straight line and supported at the ends on abutments.

Definitions of some technical terms.

Voussoirs - Are the stone blocks or bricks (usually wedge shaped) which compose the course of an arch.

Springer - Are the lowest voussoirs of the arch.

Key or Key stone - Is the topmost or central voussoir of the arch.

Sometimes a portion of the arch at the crown is made of specially worked stones or of bricks in different bond. That portion or block is then called key block.

Intrados - It is the lower concave surface of the arch.

Extrados - It is the upper convex surface of the arch.

Springing points - Are the lowest points in the curve of the arch from which the curves starts.

Springing Level - Is the imaginary line joining two corresponding springing points.

Crown - It is the highest point of the extrados.

Span - It is the horizontal distance between the springing points.

Rise - It is the vertical distance between the highest point of the intrados and the springing level.

Haunch - It is the portion of arch from the springing level upto midway to the crown.

Skew Back - It is the surface on which the springer rests.

Arcade - It is a series of arches supported on the two extremes on abutments and between the abutments on piers.

Abutments - Are the end supports of an arcade.

Piers - Are the supports of an arcade between the abutments.

Classification according to shape of blocks used.

(1) Rough Arch - It is constructed of ordinary un-cut bricks. As the bricks are rectangular in shape the joints will taper from end to end. In order to reduce the difference in thickness between the two ends of the joints, such arches are usually constructed in concentric rings each ½ brick deep.
(2) Gauged Arch - The stones or bricks used in this type are wedged shape and the joints are of uniform thickness. The stones and bricks are cut to the required shape with the help of a gauge made of wood.

Classification according to shapes of curve.
(1) Semi-circular arch - It is an arch the centre line of which is a semi-circle.

The important characteristics of a semi-circular arch are given below.

The rise of the arch is equal to its radius.

The area of opening below the arch is greater in this type than other arches of similar span. It has got a pleasing appearance.

Uses - It is often used for supporting openings of verandahs, over doors and windows with fanlights, and in small culverts.
(2) Segmental arch - This is an arch in which the centre line is the segment of a circle. The strongest arch is that in which the rise varies from 1/3rd to 1/4th span. However, segmental arches with rises varying from 1/3rd to 1/8th span are in use.

The special characteristics of the arch are the following:-

The thrust at the abutment is inclined to the vertical and causes considerable overturning moments on the support.

The centre of the arch is below its springing level and can be found by the ordinary rules of geometry.

The opening below the arch is lesser in area than the semicircular arch.

Uses - This is commonly used as relieving arch over doors and windows as well as for Jack-arches, verandah openings, culverts and bridges.

Elliptical Arch - It is one in which the centre line is a semi-ellipse.

The special characteristics of the arch are the following:-

It has got a good appearance and is, therefore preferred in buildings where appearance is an important factor.

The arch is weaker than segmental arches and is susceptible to radial shear in the haunches.

Ordinarily the rise should not be more than 1/3rd span.

Uses - This is used in verandah openings and in other prominent portions of buildings for the sake of its appearance.

Parabolic Arch - Is an arch in which centre line is a parabola. It is rarely used in buildings as its appearance is not very pleasing. But it is extensively used in arch bridges in which the arches have long spans.

Equilateral Arch - This is a two centred arch in which the two halves are segments of circles.

The special characteristics are given below.

The centre of each half is the springing point on its opposite side.

The radii of the two segments are equal.

It has got a pleasing appearance.

Uses - It is used on over doors and windows for the sake of its appearance.

Flat or Straight Arch - Is an arch the centre line of which is a straight line.

Such arches should preferably be constructed always of wedge shaped or bricks.

The characteristics of the arch are given below.

It is comparatively a weak arch and should be constructed with great care.

It has good appearance and is, therefore, used in prominent portions of the building where the brickwork is pointed.

The joints converge on the apex of an equilateral triangle formed with the span as base. Another rule followed for the inclination of the joints is that the skewback is given a slope of 1½" per foot of span for an arch of 12" depth.

During construction the middle of the centering is raised by 1/8th" for every foot of span. This rise will disappear when the arch is eased.

It is susceptible to damage by radial shear.

Uses - It is used over door and window openings and chimney hearths.

Being a weak arch, a segmental relieving arch is often constructed above it to bear the load of the masonry and the flat arch is meant mainly for appearance. Another method is to construct a concealed reinforced concrete lintel over the opening and to cover it with a facing of 4½" thick flat arch, so that the major portion of the load of the masonry is borne by the lintel.

Construction of Arches

Centering of arches - Centering is the temporary support given to arches during construction so that the voussoirs or bricks can be arranged along the necessary curve above it and support them in the required position until the arch is completed and the mortar sets. The upper surface of the

centering will have the same curve as the intrados of the arch.

Types of centering - The type centering that has to be used for constructing an arch will depend on its span. The following types are commonly used.

(1) Brick centering - This is used for small arches over doors and windows and other arches which are not often used after construction.

It consists of two or more rough columns about 1½ brick square made of dry bricks of brick bats. At times the bricks are made in mud mortar for the sake of stability. The columns arise to a level slightly below the springing of the arch. A timber board is placed over the columns, the top surface of which should be at the springing level of arch. Above this board a brick core in mud mortar is constructed. The tope of the core is finished smoothly with clay to the same curve as the intrados of arch. The arch is turned over this core by supporting the bricks on it. After the arch sets the centering is removed. In such cases where easing is not done greater care should be taken to fill up the joints thoroughly. This is often done by grouting with fluid mortar.

(2) Truss centering - These are usually constructed of timber for ordinary spans and of steel for very big spans. They consist of temporary trusses fabricated in different shapes to suit the span, hoisted and kept in the required position to support the arches till the mortar sets. Such centerings used for the different spans are described below.

(a) For small arches with spans upto 6' ribs of the shape shown in the sketch are made by nailing or screwing together 1" to 1½" thick timber boards shaped as shown. The spacing of the ribs varies from 2' to 6'. Only two ribs would be needed for arches constructed in buildings. The top

of the ribs should have the same curve as the intrados of the arch.

The ribs are connected by laggings (strips of timber) nailed over the top of the ribs. The sizes necessary for lagging are given in a tabular form.

At the bottom, cross pieces are nailed at approximately 4' intervals between the cords, to tie the ribs together.

The ribs are supported on two or more props resting on the floor. Between the top ends of props and the ribs greased wedges are introduced for easing the arch. If the floor is not sufficiently hard the feet of the props should rest on foot-plates to prevent sinking.

(b) When the span of the arch is between 6' and 12' the rib shown in the sketch is generally used. In this there are more number of timber members making up the truss and the sections should be bigger than in the previous type.

The method of joining the members and supporting them is similar to the previous type.

(c) Above 12' span for heavy arches, trusses shown in the sketch are used. The details of the type used for spans upto 20' are given in the sketches.

<u>Sizes of laggings for arch centering</u>

Spacing of ribs or trusses		Span of centering in feet. 10'	20'	50'	100'
		Thickness of lagging in inches.			
6'	..	3-1/4"	3-5/8"	4-1/4"	4-3/4"
5'	..	2-1/2"	2-7/8"	3-3/8"	3-5/8"
4'	..	1-7/8"	2-1/8"	2-1/2"	2-3/4"
3'	..	1-1/4"	1-3/8"	1-3/4"	1-7/8"
2'	..	3/4"	7/8"	1"	1-1/8"

<u>Easing of Arches</u>

Easing means gradually depriving the arch of its temporary support and allowing the weight of the new structure to be gradually transferred to the abutments.

The centering should be lowered 1/2" within 12 to 24 hours after the arch is complete. The usual practice is to construct the masonry in the spandrils called 'backing' upto haunch height before striking the centre.

The mortar joints are compressed by easing. The arch is then allowed to set for 12 to 15 days. The centering is then struck (removed).

The following are the common methods of easing arches:-

(a) By wedges - Hard wood wedges with 1/2" or more taper and greased surfaces are placed between the ribs and the tops of the props. Nails are driven into the wedges to prevent slipping. The nails are removed when easing has to be done and the wedges struck in the opposite directions to lower the ribs.

(b) Sand box method - A wooden box of internal dimensions about 1" greater than the feet of the props is filled with dry sand up to a few inches lower than the top of the box. The foot of the prop is made to rest on a timber board placed over the sand. This board should be sufficiently thick and its dimensions slightly smaller than the internal dimensions of the box. There are holes on all sides of the box to let out the sand whenever necessary. When the arch has to be eased the sand is gradually let out by removing the plugs until the prop sinks to the required limit. It is important that all of them should be lowered uniformly and gradually.

(c) Screw jack - This is a more accurate and convenient method. It is used for the big arches of bridges. The feet of the props rest on screw jacks placed on foot-plates over the floor. When the arch has to be eased the jacks are lowered uniformly to the required extent.

Thickness of arches in buildings

Span.	Thickness of brick arch.	Thickness of stone arch.
3' ..	1 brick (9")	9"
4' to 8'	1½ bricks	12"
9' to 30'	2 to 2½ bricks	18"

Abutments of Arches

Span		Minimum size of abutments
4'	...	2'
5'	...	2¼'
6'	...	2½'
8'	...	2¾'
10'	...	3'
15'	...	4'
20'	...	5'
25'	...	6'

Hollow Walls

Wherever economy in masonry as well as resistance to dampness and insulation is desired, for ordinary single or double storeyed residential cottages, hollow walls are suitable. It is most useful for exterior walls of buildings; but it can be adopted for internal walls also due to its good insulation of sound.

It consists of two separate walls called 'leaves' or 'skins', with a hollow space of 2" width between them.

Leaves - These are the two separate walls between which is the hollow space. Thus a hollow wall equivalent to 1 brick thickness would consist of two half-brick leaves and a 2" wide cavity thereby making up a total of 11" thickness. Such walls are suitable for light constructions such as single storeyed cottage type residences, when economy in masonry is desired. In the case of thicker walls the common

practice is to build the outer skin of half-brick thickness in stretcher, Flemish or Flemish garden wall bond and the inner of 1 brick or more thickness of any suitable bond. For buildings with a stone facing the outer leaf is built of stone wall 4½" to 9" thick and the inner wall of bricks.

<u>Ties</u> - These are the connexions between the leaves to bind them together. They are made of galvonized iron or of ordinary flat iron, or copper, galvanized wire and iron rods bent to the required shape and painted with tar. The wire ties should not be thinner in gauge than 10 B.W.G. (.134" diameter). These are about 8" to 9" long and shaped like 8 or two triangles meeting at their appex.

The flat iron metal ties are also 9" long, ¾" wide and 1/8" to 1/4" thick with their ends forked out to 2" to 2½" width by halving the width of the strip near the two ends. A twist in the middle of its length helps to arrest the passage of water drops if any creep along it.

At times specially made locking bricks are built into the two leaves to act as ties. But they are liable to transmit dampness to inner wall. Brick ties are not as strong as the metal ties.

The metal ties are fixed at intervals of 3' horizontally and 1'-6" vertically. At jambs of doors etc., additional ties should be fixed at the edges of the walls to prevent separation of the leaves. The leaves should be joined up with bricks all around such openings as well as on the tops of walls.

If footings are constructed the cavity is often not continued through them.

Mortar and brick chippings should not be dropped into the cavity or on the ties as this is one of the causes for dampness in hollow walls. To prevent this a wood batten which fits loosely in the cavity should be placed over the ties where the wall is being built, to collect any droppings of mortar

etc., from the mason's tools. The batten should be raised and cleaned frequently so as to remove any accidental droppings.

ROOF

Roof is the external upper covering of a building. It includes the frame work or other types of structures supporting the roofing material and the roofing material itself.

Purpose - The roof is meant mainly to protect the interior of the building from atmospheric action such as rain, sun, snow etc. and to keep the interior dry, cool and comfortable.

Pitch of roof - Pitch means the slope of the roof.

The pitch of a roof can be expressed in the following manner:-

(a) Expressing the rise in terms of a fraction of the span.

Example - Pitch - ½ span or 1/3 span.

The term pitch in this case stands for the rise or the vertical height of the roof slope.

(b) As an angle which usually denotes the angle the surface of the roof makes with the horizontal.

The main factors which effect the choice of pitch and the roofing material.

(a) Climatic condition:-

(1) In the high hills where there is snowfall the roof should have a steep pitch so that much snow may not accumulate on the roof and may slide down when it attains a small depth. Accumulation of snow on roof top causes very heavy loads on roof timber which should be prevented. At the same time there is greater wind pressure on a roof with a steep pitch, which is also not desirable. In areas which are subject to strong wind the pitch should be lower than in sheltered areas. Pitches varying from 1/8 to 1/2 span are adopted for pent roofs depending on the climate and other factors.

(2) In localities where rainfall is very heavy the pitch of roof should be steeper so that the rain water may

flow down the roof slope quickly without accumulating and causing leaks through the joints. The pitch in such cases will depend on whether the roofing material is thoroughly impervious like C.G.I. sheet or slightly pervious like tiles etc. In the later case the pitch can be less steep than in the former.

(3) In dry areas in the plains where rainfall is low flat roofs can be used. If pent roof is used in such areas the slopes can be reduced depending on the comparative intensity of rainfall and the type of roofing material.

(b) Type of roofing material:-

(1) Corrugated Galvanised Iron Sheets - This is made of pressed metal sheets and is a thoroughly impervious roofing material. It can resist heavy rainfall without leaks, even with a gentle slope, and the shattering effect of hailstorm. It can be fixed rigidly to the timber members of the roof due to which it can resist strong winds. It is very durable.

The main defect is that it absorbs heat considerably and cannot be used in localities where summer temperatures are very high. Even in other places it requires a good ceiling to keep the interior cool. It is noisy during hailstorm.

The pitch of C.G.I. Sheet roofing varies from 1/8 to 1/2 span. 1/2 to 1/3 span is usually used in the high hills where there would be snowfall. In the plain areas the pitch varies from 1/4 to 1/8 span.

(2) Asbestos sheets - It is available in the market with different types of corrugations under various trade-marks and names, e.g. Big Six Everest Trafford Sheet etc.

It resists transmission of heat far better than C.G.I. sheets. It absorbs moisture slightly. It does not crack due to ordinary hailstorm but may be effected by very severe ones. It is generally used in the plains where there is heavy rain as well as high summer temperatures. It is a

fairly durable type of roofing material and can be fixed rigidly to the roofing member in a manner similar to C.G.I. sheets.

The pitch varies from 1/8 to 1/3 span.

(3) Tiles - Clay tiles manufactured for roofing in various shapes are fairly impervious if the roof has the required slope, so that the rain water can run down the valleys of the tiles quickly. It absorbs lesser amount of heat than the C.G.I. sheets. But it breaks during hailstorms; otherwise it is a durable type of roofing material. It is gnnerally used in the plains where there is heavy rainfall and moderately high summer temperature. Good clay is necessary for manufacturing the better type of roofing tiles. The tiles are liable to be blown away by strong winds.

Pitch of tiles should vary from 1/2 to 1/4 span depending on the intensity of the rainfall.

(4) Shingles - The shingles ordinarily used are made of timber or slate.

Timber shingles have good insulating properties against extremes of temperature and can resist hailstorm and snow. They can be fixed rigidly to the roofing member. The durability depends to a great extent on the type of timber used and whether the shingles are treated or not. The timber should not be liable to warp and split.

It is generally used in the hills where durable timber is available cheaply and in the plains as an external insulating cover for C.G.I. sheet roofs.

The pitch of the timber shingle when used alone as the roofing material varies from 1/2 to 1/3.

(5) Slate - Slate shingles are used as roofing where good slate beds occur. The qualities of the shingles vary according to the type of slate - on the whole if the shingles are thick it is a heavy roof material. It is also very

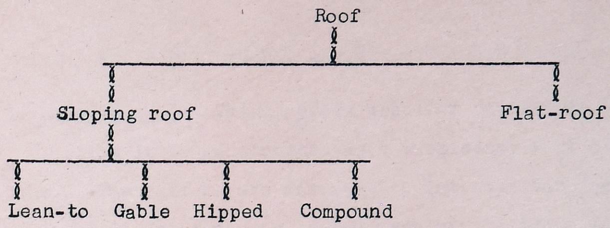
difficult to fix such shingles to the roofing timber. It can resist hail and snow and is used in the hilly areas where slate beds occur naturally. The shingles are cut to different sizes and are known by different names.
The pitch varies from 1/3 to 1/2 span.

(6) <u>Thatching</u> - It is most pervious of all roofing materials, and not very durable either. Two to three years is ordinarily its useful life and requires renewal or extensive repairs after this period. It is inflamable in the dry condition. It is a good insulator of heat and cold and is used in areas where thatching grass or other materials used for thatching are available locally. The roof timber need not necessarily be sawn but round ballies and bamboos can also be used.
It is used in temporary structures as well as places where other roofing materials are not easily procurable.
Thatch requires a high pitch. Thepitch used is 1/2 span.

(7) <u>Flat terraced roof</u> - Such roofs are generally used in the dry plain areas with comparatively little rainfall. Several types of constructions with bricks, tiles, concrete etc., are in common use. It is a heavy type of roof and requires heavy reinforcement in the case of concrete roofs and large sized timber beams for brick terraced roofs. Any cracks that may occur in such roofs are difficult to repair and due to this it is popular only in the dry areas. However, carefully constructed R.C.C. roofs serve fairly well also in areas where there is moderate rainfall.
The slope is very small and usually about 1 in 48.

<u>TYPES OF ROOF</u>

The following is the main classification of roofs according to shape:-



The above classification is based on the overall shape of the roof.

PENT ROOFS.

(1) Lean-to roof - A lean-to roof has only one slope. It is generally used as a subsidiary roof over verandahs or at extensions of a main roof to cover unimportant rooms as well as in out-houses etc., where the span is very small.

(2) Gabled roof - It has two slopes meeting at the ridge. The ridge is equal in length of the roof. The roof may end with gabled walls or is extended about 12" to 18" beyond its outer face for protecting the wall.

(3) Hipped roof - This type of roofs has four slopes namely two side slopes of trapezium shape and two end slopes triangular in shape. Ordinarily all the slopes has the same pitch. The length of the ridge is equal to the length minus breadth of the roof if the four sides of the roof have the same slope.

It has a better appearance than gable roof but is more difficult to construct.

(4) Compound roof - It is roof in which the various types mentioned above are combined. Valleys are formed where two slopes of different roofs meet. This type of roof is used more on important buildings with long plinth areas and where appearance has to be pleasing. It is more difficult to design and construct.

(5) Flat Roof - Terraced roofs are constructed of bricks, tiles, R.C.C. or Jack arch etc. The details of its construction are dealt with later.

CONSTRUCTION OF ROOFS

1. Lean-to roof - This type is used for spans upto 10'.

Often it is constructed as a subsidiary roof over verandahs. The rafters are fixed at an interval varying from 15" to about 4'-6" depending on the type of roofing materials, the sizes of the timber and span. 15" to 24" spacing is generally used for tiles depending on the size of battens, rafters, and weight per square foot of roofing material. For C.G.I.sheets, G.I.Sheets and asbestos sheets, the spacing varies according to size of rafter, purlins, gauge of the sheet etc. The spacing for such sheets varies from about 2' to 4'-6" centre to centre. The sizes and spacing of the timber members should be ascertained by design.

The top of the sloping rafters are fixed on wall plates by birds-mouth joints and secured by inclined nails or spikes. The bottom end of rafters are fixed similarly over the bressumers. The rafters should project beyond the plinth wall about 1'-6" to 2' horizontally.

Over the rafters, purlins or battens are nailed at the required spacing which will depend on the kind of roofing material. The roof material is fixed directly over the battens or purlins.

Methods of fixing wall plates

(a) Corbelled course method - A corbelling course 4½" wide is built along the wall at the appropriate level. The wall plate of the roof is fixed over the course with mild steel strap about 2½" x 3/16". One end of this strap is bent at right angles so as to hold the wall plate in position and the other end is built into the wall. The built-in end is also bent so that it can be properly bedded in the masonry. Such straps are spaced at the intervals of 5' to 6'.

(b) <u>Corbel-stone method</u> - Cut stone or R.C. corbel of about 4" x 4" cross-sectional dimension and bent at the projecting end are built into the wall through its thickness at intervals of about 3' to 5' depending on the weight of the roofing etc. The wall plate is supported over the corbel stones.

2. <u>Couple-roof</u>.

When the span of the roof varies from 10' to 12' a couple-truss is usually used.

It consists of rafter couples fixed at intervals of 18" to about 4'. The spacing depends on the factors mentioned in the previous case. The sizes are determined by design. As there is no tie between the rafters, they transfer a thrust which is inclined to the vertical, directly to the walls and the rafters themselves are liable to bend. Hence the span of such a truss is usually limited to 12'. Other timber members like purlin, battens etc., to which the roofing material is fixed as described later.

<u>Joint at the top rafters</u> - Method I:- The top ends of rafter are cut slanting to butt against the vertical face of a central horizontal member called Ridge Piece. These inclined faces are butted against the ridge piece and spiked.

The ridge piece is usually a very thin deep beam spanning from one end to the other end of the ridge.

<u>Method II</u>:-The top ends of the rafter are bolted together with a bolt of diameter about 3/8" to 1/2". In this case a ridge piece is often not used.

If a ridge piece is used one method is to cut a birdsmouth joint in each of the rafter at its top end and fixed them above the ridge piece in addition the rafter ends are joined together with a bolt.

<u>Method III</u>:- This method is adopted only for gabled roof when C.G.I.Sheets are used as roofing material. In that case a ridge piece need not necessarily be used.

The rafters are lapped and bolted together at the top with 3/8" bolt. Such a roof frame work is made laterally stable by the purlins which are fixed between the trusses.

Joinary at foot of rafter - The foot of every rafter is fixed to a wall plate by a birdsmouth joint which is spiked.

Wall plate. It is a long piece of timber rectangular in section fixed along the top of wall over which a number of rafters at close spacing are supported.

The wall plates distributed the load of the roof uniformly over the wall and is the timber member over which rafters can be rigidly connected.

Joints for lengthening the wall plate and at right angular junctions are ordinary halving joints secured by nails or screws.

The wall plates are fixed to the walls either by building them into a masonry in which case they are usually placed in the middle of the wall thickness or by embedding mild steel rods of about 3/4" to 1" diameter in concrete blocks about 9" square and 6" deep built into the walls at approximately 5' to 6' interval. The projecting portion of the bolts are passed through holes in the wall plate and tightened in a suitable manner.

The wall plates should be thoroughly creosoted before fixing it in position and durable timber should be used.

3. Collar-truss.

This is used when the span of the roof varies from 12' to 14'.

In this type of truss in addition to the rafters a horizontal member called Collar or Collar beam is fixed 1/3 to 1/2 way up the length of the rafter. For this purpose length of the rafter from wall plate to ridge piece only is taken into account.

Collar acts as a strut (Compression member) resisting the deflection of the rafters in case the walls do not yield at all to the thrust. If walls or connections at feet of rafters yield, then the collar acts in tension.

Joints at the top and bottom of rafters are more or less similar to the couple truss with the difference that the faces of the two rafters forming the truss should be in the same plane. This can be achieved by halving the top ends of the rafters before bolting. This would be necessary if ridge piece is not used in the construction.

Joint between rafter and collar - One method is to lap and bolt the two ends of the collar with the rafter with bolts about 3/8" diameter. The bolt holes should be bored in the centre of the depth of both members. A round washer should be placed below the nut.

An alternative method which is better, is to halve the two members in a dovetail form. Only one edge of the collar is cut as a dovetail. To reduce the depth checked out in each member only 1/4th the thickness of each member is cut out in the halving. The joint is secured by two or three screws or wooden nails (trenails).

The other members of the roof are fixed in a manner similar to the previous type.

When a truss is used for the roof there would be more head room below the ceiling as the ceiling is generally fixed directly to the rafters and the collar.

4. Close-couple truss.

Close couple trusses are used when the span of the roof varies from 14' to 16'.

In this type of truss a member called tie beam is fixed between the feet of the rafters to act as a tie (Tension member).

The main defect of this truss is that a tie beam of

nearly 16' length is liable to sag. This is often overcome by fixing a mild steel rod between the centre of tie beam and the ridge. It is then called King-rod truss.

Due to the difficulty of fabricating a proper king rod truss very often over 16' or more spans a king post truss is used.

The joint between the foot of the rafter and end of the tie is a plain lapped and bolted joint. A halved joint is not often used in this because a part of the rafter has to be cut for the birdsmouth joint and further weakening near the same section has to be avoided.

The other joints and connections are similar to the trusses described previously.

5. <u>King-Rod truss</u>.

This is used for span varying from 16' to 18'. It consists of members similar to the close couple truss and a king rod in addition which prevents sagging of the tie beam. The king rod is usually 1" diameter mild steel rod which acts as a tension member.

The simplest method of constructing this truss is to use a ridge piece and pass the top of the king rod through bores in the ridge piece and the bottom of the rod through the tie beam.

6. <u>King Post truss roof</u>.

This truss is used for spans varying from 18' to 30'.

It consists of two principal rafters (compression member), a tie beam (tension member), a king post (tension member) and two strutts (compression member) joined together as shown in the sketch. The strutt is generally fixed in the middle of the length of the principal rafter and resists bending of the rafter. The foot of the king post is fixed in the middle of the tie beam.

The joints between the different members of the truss are described below:-

(a) Joint between principal rafter and tie-beam.

The common joint used is a oblique-tenon. Details of the joint are shown in the sketch. A mild steel strap or bolt is fixed at the joint to prevent the members from moving apart.

A bridle joint may also be used at this junction of the truss.

(b) Joint between head of king post and principal rafter.

The joint used commonly is a tenon joint in the slanting shoulder portion of the head of the king-post.

The head of the king post is made wider by doubling its width at the top. The mortice (the hole) is cut in the slanting face of the king post head and the tenon in the principal rafter. In another form of the same joint part of the mortice is cut in the king post and part in the slanting face of the kking post head. Three-way mild steel straps are fixed with bolts on both faces of the truss to keep the members together.

At the top of the king post a slot is cut to receive the ridge piece, if it is used.

(c) Joint between the feet of king post and struts.

This joint is similar to one described above.

The three-way strap used at this joint should pass around the tie beam so that the king post and the tie beam may be fixed together.

(d) Joint between tie beam and king post.

A stub-tenon joint is commonly used. Its detailsx are shown in the sketch.

The tie beam and king post are fastened together by a separate strap of U-shape, or it may be a part of the Three-way strap between the king post and struts.

(e) Joint between strut and principal rafter.

The joint commonly used is oblique-tenon joint. Details are shown in the sketch.

Three-way straps are fixed at this joint also.

Details of construction of roof with king post truss.

1. With C.G.I. Sheet as roof cover.

The spacing of the trusses varies from 8' to 12'.

A thumb rule which can be used for finding the minimum spacing for loads of roof from 30 to 60 lbs. per sq. ft. is given below:-

$$D = \frac{Span + 4\frac{1}{2}}{3}$$

Where D is spacing in ft.
Span in ft.

If ceiling joists are attached to the tie beam of truss, 3/4th of the spacing worked out by the formula would be the minimum spacing. The spacing between all the trusses between the ends of the ridge or between cross-walls should be equal.

The trusses are fabricated by marking the central lines of various members and their edges on a hard floor, and cutting the members and joints to the required sizes. The different members are joined together to form the truss.

Templets of concrete or cut stone usually square in shape of size equal to the thickness of the wall and about 6" deep is cast in position, or built into the masonry in the places where the trusses have to rest. An iron bolt about 1" diameter is imbedded in the centre of the template throughout its depth. Sufficient length of the bolt should project out so as to pass through the ties beam of the truss as well as to fix the nut to tighten the truss.

The bolt is passed through the portion of the tie beam projecting beyond the joint with the principal rafter and fixed with nuts. The trusses are lifted and placed in position with the help of improvised derrick.

When C.G.I. sheets are used as roofing material it is not necessary to fix a ridge piece over the trusses.

Purlins - These are beams spanning between the principal rafters of the trusses. The spacing between the purlins depends on the gauge and size of sheet, size of purlins and spacing of trusses. The purlin at eaves is fixed such that

its lower vertical face is about $1\frac{1}{2}$" to 2" away from the end of the rafter. If a cleat is fixed it should be possible to accommodate the cleat. The top-most purlin on every slope should be fixed in such a position as to receive the screws or bolts used for fixing the ridge cover. The purlins in between these are fixed at equal spacing.

Cleats are fixed below purlins to prevent them sliding and the purlins are spiked to the principal rafter. An alternative method is to notch the rafter to a depth of $\frac{1}{2}$" and spike the purlin in the notch. This method weakens the rafter to some extent. Necessary allowance has to be made for it in depth.

C.G.I.Sheets are fixed as described later.

Extension of principal rafter for eaves.

Method I - The common method is to attach an additional piece of the same section as the principal rafter on the side of the principal rafter by lapping about 2' length and bolting or screwing the two together.

Method II - Shorter sections of rafter are built into the masonry at intervals of about 2' to 3' and the purlin is fixed over them.

2, With tile or shingle as roof cover.

In this case additional smaller rafters called common rafters have to be fixed at close intervals, as the battens which supports the tiles are small in cross section. The spacing of the common rafters varies from 18" to 24". A section 4" x 2" is commonly used for the above spacing. The size of battens for about 24" spacing when Mangalore tile is used, is 2" x 1". If heavier type of tile roofing such as double Allahabad tiling is laid, the spacing of the rafters should be reduced or the size of the battens should be increased. The spacing of the battens will depend entirely on the type of tile used.

A ridge piece is necessary in this type of roof. It is fixed in the slots cut at the head of the king post. The top end of the common rafter are fixed to the ridge piece by nailing the rafter and to the vertical faces of the ridge piece.

Purlins - One purlin is fixed over the principal rafter above the joint between the strut and the principal rafter. The spiked joint is strengthened by a cleat. For lengthening the purlin the halving joint should rest over the principal rafter.

Pole Plate - Is a beam fixed over the end of the tie beam on which the feet of the principal rafters are joined by a birdsmouth joint. The height of the beam should be so designed that the principal rafter can be joined conveniently above the pole plate..

Common rafter - Smaller rafters called common rafters are fixed at close intervals to support the tiles. The heads of the rafters are butted and nailed to the ridge piece. The joint over the purlin may be a plane spiked joint or the rafter is notched to depth of 1/2". The joint between the pole plate and rafter is a birdsmouth joint.

The common rafters should project beyond the wall to form the eaves of the roofs as is described previously.

Battens - The size of the battens used has already been mentioned. The minimum length of pieces of battens should be equal to centre to centre spacing of four rafters. Battens are lengthened by plain nailed joints over the rafter. Spacing of the battens depend on the type of the tile used. Centre to centre spacing is 6" if flat tiles are used, 12½" for Mangalore tiles alone and 12" for Allahabad tiles. The battens should be nailed down with 1½" to 2" long wire nails.

Tiles - The way in which different types of tiles are laid is described later.

G A B L E S

If the end of the roof is gabled the construction is as follows:

The trusses are fixed at equal intervals between the gabled walls. The ends of the roof are supported by the gable wall. This is done by building in the purlins directly into the gable wall or over a sloping wall-plate fixed over the gabled wall. If the roof covering is C.G.I. sheet is it laid to cover the top of the gable wall also or it is built into the gable wall for a length of about 6". The gable walls are built above the roof with sloping courses of bricks or stones to a height of 1' to 2'. The top of the wall should be covered with a coping.

H I P S

When the end of the roof is hipped there should be one truss at each end of the ridge. The other trusses should be at equal intervals in case there is no cross wall supporting the ridge piece. If there are cross walls their tops should be gabled and should support the ridge piece at intervals. The trusses should then be equally spaced between the cross walls.

Hip rafters are fixed between the top of the trusses at the ends of the ridge and the junction of the walls. The top surface of the hip rafter should be at the same level as the principal rafters of the trusses so that the level of the purlin may be the same over the trusses as well as the hip rafter.

Joint at head of hip rafter - The top end of the hip rafter is joined at the top of the truss by cutting the ends oblique to its length and spiking it to the truss. Sufficient space should be left between the two hip rafters to accommodate the central jack rafter which is also joined

to the truss between the two hip rafters by a similar joint.

To strengthen the joint a dwarf collar should be fixed between the two principal rafters immediately below the joint of the hip rafter. The level of the collar should be such that the hip rafters can be fixed by a spiked birdsmouth joint to the top surface of the collar.

<u>Joint at foot of hip rafter</u> - If there is no wall plate a concrete or cut stone template in which an iron rod is imbedded is built into the wall at the junction. The bolt is passed through a bore in the hip rafter add tightened with a nut. At times the bottom surface of the hip rafter is suitably notched to fit over the template.

<u>Jack Rafters</u> - These are rafters of different length supporting the hipped end of the roof. Their top ends are fixed to the hip rafter and the bottom to the wall plate or built into the masonry. They should be fixed in such a way that their top surfaces are at the same level as that of the hip rafter. Ordinarily the section of all hip rafters are equal irrespective of its span.

The top ends of Jack rafters are bevelled at the necessary angle to butt against the face of the hip rafter and the joint spiked with at least two spikes. The bottom ends are joined to a wall plate if there is one, by birdsmouth joint. Otherwise they should be built into the masonry.

ROOFING - MATERIALS

The different types of roofing materials ordinarily used have already been described. The method of fixing such roofing materials over the roof are given below.

1. Tile roof with pan tiles over flat tiles.

Battens of 2" x ½" size are nailed with 1½" nails at 6" centre to centre spacing over the common rafters. The length of each piece of batten should not be lesser than the distance between four rafters. The joint between battens should be nailed plain butt joints over the rafters. Least number of such joints should come over each rafter. The lowest batten should be double the thickness of other battens so as to raise the edges of the bottommost row of tiles. The top surface of the battens should be tarred or creosoted.

Flat tiles are soaked in water for at least 4 hours and their under-sides should be whitewashed if there is no ceiling. These tiles are then arranged side by side in rows, starting from the bottom upward. Joints should be broken in adjacent row.

Over the flat tiles a layer of lime mortar about 3/4" thick is spread and the first layer of pan tile are pressed into it side by side in rows, with their concave surfaces upward. The wider end of every tile should come on the higher side of the slope and the thinner end of the tile in the upper row should fit into it. The lap of the tiles in adjacent rows should be half the length of the tile.

A second layer of tiles is laid similarly with their convex surface upward, covering the joints between the tiles of the lower layer. The lap between the tiles in adjacent rows of this layer should be 2/3 the length of the tile.

Ridge and hips - Special ridge tile of semi-circular sections are used to cover the ridges and hips. Both edges

of such tiles should be set in lime water. The lap between these tiles should be half the length of the tile.

2. <u>Tile roof with pan tiles alone</u>.

The method of laying is the same as above except that this spacing of the battens is 4" and the layer of flat tiles and lime mortar over it is omitted.

The defect of this type of tiling is that the tiles are liable to be blown away by wind. It can be prevented by fixing wind tiles at close intervals.

3. <u>Mangalore tile roof</u>.

The spacing of the rafters of 2"x4" to 4½" size varies from 18" to 24".

Battens of 2" x 1" size are fixed with 2" nails at a spacing of 12½" centre to centre. The battens at the eaves should be double the thickness of others.

These tiles have 4 buttons, two near the top end and two near the bottom end, on the under side of the tiles. The buttons at the top butt against the upper face of the battens, and the buttons at the bottom against a groove near the upper end of the tiles in the lower row, over which it laps to a certain extent. The side joints are made leak-proof by two grooves along one of the long edges of every tile into which similar ridges in the adjacent tiles fits neatly.

Tiles near hips, valleys and ridges may be broken to fit. The hips and ridges are covered with special ridge tiles triangular in cross section and having grooves on the underside at one end and corresponding ridges at the other end of each tile which when fitted together in adjacent tiles formsa leak-proof joint. The ends of ridge and hips tiles should be set in mortar and neatly finished.

All tiling work should be started from the eaves upwards.

<u>Wind ties</u> - In exposed windy areas flat iron strips

about $1\frac{1}{2}$" x 1/8" are fixed over the tiles along the length of the roof and screwed down through the tiles to the rafters. Ordinarily the row of tiles at the eaves only are thus tied down, but in very windy areas wind ties should be fixed at about 6' intervals along the slope.

4. Allahabad Tile roof.

The common type of this tiling consists of a lower layer of tiles which are laid flat. These tiles have a tapering section and verticles sides, the top ends of which are recessed. The tile in the upper row fits neatly into this portion of the tile in the lower layer over which it laps.

The covering tiles are usually trapezium shape in cross section and have a taper from one end to the other. There is a recessed portion at one end so as to fit with the tile in the upper row. The thinner end of the tiles should come on the upper side when laid.

When this type of tiling is laid in single layer the sizes and spacing of rafters are the same as for Mangalore tiles.

The battens of 2" x 1" size are fixed at 12" centre to centre spacing in accordance with the previous specifications.

Tiles are arranged with their wider ends upwards over battens in rows starting from the eaves. They are held firmly by buttons which butt against the upper face of the battens.

The covering tiles are placed over the opened joints of the flat layer of tiles. The covering tiles lap over one another which makes the joints between them leak-proof. The covering tiles are usually set in lime mortar to prevent from being blown away by wind.

5. Corrugated galvanised iron (C.G.I. sheet roofing).

C.G.I. sheets are available in different gauges. 18 to 22 B.W.G. sheets are generally used for roofing. They are available in lengths varying from 5' to 10'. The common width is 10 corrugations each corrugation being 3" wide and 3/4" deep.

The purlins are usually fixed directly over the trusses. Spacing etc., have been previously discussed. There should be 2 purlins below the end joints of every sheet and one or more purlins should come in between these according to necessity.

The sheets are fixed to the purlins by the following methods:-

(a) With hook or J-bolts - These bolts are made of mild steel rods about 1/4" diameter, bent in the form of a hook or J. The width of the hooked portion should be the same as the width of the purlins. A length of about 1" to 1½" of the bolt with screw thread cut on it should project beyond the ridge of the corrugation to fix a cup or limpet washer and nut. The other end should have sufficient length to grip the purlin properly. Ordinarily three such bolts are fixed along the width of each sheet. In exposed windy areas the bolts should be more in number. The bolt holes should be in the middle of the ridge of the corrugations and should be about 1/16" bigger than the diameter of the bolt to allow for expansion and construction. Limpet (cup-shaped) with flat washers placed below them should be used below every nut to make a leak-proof joint. Along the length of the sheets ordinary galganised iron, nuts and bolts should be fixed at intervals of about a foot. This is the most satisfactory method of fixing the sheets.

(b) By screws.- The sheets can also be fixed to the

purlin with screws placed on every third corrugations. A flat washer should be placed below the head of every screw and the screws should be long enough to penetrate to a depth sufficient to hold the sheets. Iron screws are liable to rust in which condition they are easily pulled out of the timber.

F L O O R S

Object: Floors are built to provide a flat surface inside the buildings which is hard, durable, moisture proof and easy to be kept clean.

Types of floors: The common floors laid in residential and other buildings of the ordinary type are given below:

1. Brick-on edge floor
2. Tile floor
3. Cement concrete floor
4. Mosaic or terrazo floor
5. Wooden floor

The details of construction the merits and demerits and the suitability of each type are described below. It should be borne in mind that it is important to lay the type of floor which is suitable for the type of the building (residential cottages, offices etc), the climate of the locality, the availability of the materials required for constructing it and other factors.

Brick on edge floor

This type of floor is useful for ordinary ground floors when an ornamental floor is not required, in places where good hard burnt bricks are available cheaply.

Advantages: It is a cheap type of floor easy to be laid by ordinary masons with bricks and mortar only.

Disadvantages: Most important defect of this type of floor construction is that the bricks wear out by abrasion quicker than the other harder materials like stone slabs, cement concrete etc. This makes the floor dusty and difficult to be kept absolutely clean. When furniture etc. are moved about over it, the bricks are often crushed at the corners and the pointing of the joints are damaged. The floor absorbs a certain amount of moisture especially in very wet localities which is on the whole unhealthy.

Construction of the floor.

Basement filling: The space between the plinth walls should be filled up with earth and brick bats or broken stones. This filling should be carefully done in layers of 6" to 12" depth and every layer consolidated separately by wetting and ramming with heavy wooden or cast iron hand rammers. This is an important operation in laying a floor as any later settlement in the filling will be reflected on the top courses, producing cracks on the finished surface. The overall depth of the filling should be the height of the plinth wall above the ground level minus the total depth of the other flooring courses.

Usually the earth left over after filling in the foundation trench should be utilised in the basement filling and only the additional quantity required is obtained from excavations away from the building site. Soils such as clay which shrink on drying causes settlement in the basement filing and sand brick-bats, broken stone etc. should be added in the filling to prevent excessive shrinkage.

Sand cushion: 3" deep layer of dry sand is spread above the earth filling as a cushioning layer for the top flooring courses.

Brick courses: The first layer of bricks is laid over the levelled sand after soaking them thoroughly in water so that they do not absorb any water from the mortar. The joints between the bricks should be of lime or cement mortar and they should be well grouted.

The second layer of bricks is laid flat after spreading about 1/2" thick layer of mortar over the first course. The joints of this and the first layer should be broken and should be grouted well with mortar. The bricks may be arranged either in a direction parallel to the walls or diagonally. The third layer of bricks are laid on edge. These should be very well burnt hard bricks and are laid

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in a similar way after spreading a layer of 1/2" thick mortar. These joints should also be grouted and they should be broken with respect to the lower layer. The top of the joints of these bricks should be pointed with rich cement plaster and neatly finished.

After construction the floor should be cured in a manner similar to concrete for a few days.

TILE FLOOR

The preparation of the basement filling and sand cushion are done in a manner similar to the previous type. The sand cushion should be wetted so that it may not absorb moisture from the concrete. A layer of lime concrete of 1 : 2 : 4 proportion is laid over it and consolidated by continuous ramming. Either brick jelly or broken stone can be used as coarse aggregate of this concrete. It should be allowed to set and harden properly for not less than about 10 days before the tiles are laid.

The flooring tiles which are generally ornamental or plain clay tiles, mosaic and other patent tiles are laid over the concrete, after wetting its surface, in a thin layer of cement mortar (1:2 mix) by pressing them into the plastic mortar close together and filling the joints and finishing the top carefully with cement mortar. The thickness of the joints between should not exceed 1/8".

The arrangement of the tiles may be either diagonal or parallel to the walls. In case there are patterns on the surface of the tiles the adjacent tiles should be laid in such a way as to exhibit the final pattern on the completion of the floor. Pattern drawings are often available along with the patent tiles in the market.

The floor should be cured for about 7 days before it is used.

Stone slab floor

The basement, sand cushion and lime concrete courses of this type are similar to the tile floor.

The stone slabs commonly used for flooring are Cuddapah slabs, slate and other similar stones which have a stratified formation so that they can be split into thin slabs without difficulty. Slabs are cut to the required thickness. e.g. about 3/4" in the case of fine slates and about 1" to 1½" in the case of Cuddapah slabs and 1' to 2' square, rectangular etc. in shape.

A layer of lime or cement mortar about 1/2" to 1" thick is spread over the wetted lime concrete layer and the slabs are pressed into it one by one leaving as fine a joint as possible. The joints should then be filled up completely with mortar and their tops finished with fine cement plaster and rubbed down to a polished finish.

Cement concrete floor

Basement filling, sand cushion etc. are laid in a similar manner as described above. In the case of floors subjected to heavy loads such as depots, workshops etc. or if the filling is liable to subside otherwise due to the nature of the earth used in filling, a 6" deep bed of well packed rubble should be laid above the basement filling before the concrete courses are laid. Then the sand chsion course is often ommitted.

Lime concrete course:

After the lime concrete sets partially i.e., about two or three days later, its surface is divided into compartments in which the cement concrete slabs are laid. The size of these compartments vary from 5' to 8' square or rectangle. Slabs 1' to 2' wide and about 4' to 5' long are laid close to the walls. The rest of the space only is subdivided into compartments as mentioned before. The form work usually consists of strips of flat iron about 1/8" to 1/4" thick or

wood about 1" to 1½" wide. The depth of the strips should be equal to that of the cement concrete slab. They should be greased to prevent the concrete adhering to it after setting. The strips are fixed in the required position by driving pairs of nails on both sides at about 1' spacing in to the lime concrete. These nails should be removed later along with the form work.

Cement concrete course:

The lime concrete slabs should be wetted well and the compartments formed are filled with cement concrete of mix 1½" to 2" thick. For thin slabs the maximum size of coarse aggregate should be 3/4". A mix of wet consistancy is the most suitable for such slab work. The thickness of the slab varies from 1½" to about 3" to 4". For ordinary residential floors 1½" to 2" thickness will be sufficient. But for floors which have to bear heavy loads such as depots, godowns etc. the thickness of the slab should be more.

The surface of the lime concrete should be well wetted before the cement concrete slab is laid. The laying should start by filling up the compartments farthest from the entrance to the room so that the least amount of trampling may be done on finished slabs. Alternate slabs should be laid on the first day. By the time these set, the edges of the slabs would serve as the mould of the slabs yet to be laid. If expansion joint are not necessary, it would be advisable to grease the sides of the slabs which have set, so that the new slabs do not adhere to the previous ones. After the first series of alternate slabs set, the forms may be removed so that they do not remain between the slabs. The concrete should be rammed lightly with a small hand rammer when a cream or cement slurry rises to the top. Excessive rise of slurry should be avoided by reducing the ramming to the minimum required for consolidation, as this produces a friable surface. Smoothening the top of the

slab should then be commenced by levelling with a wooden stock and later floating with a smooth iron float. The operation on one slab should be commenced and completed within 20 to 30 minutes after the addition of water to the concrete. Sufficient labour and materials should be employed keeping this in view.

Curing: After the slab has set i.e., about 12 to 24 hours later, curing of the slabs should start and the required dampness should be maintained for about 10 days as described previously.

If the floor is to be well polished the surface should be rubbed down with pumice stone after wetting it well.

MOSAIC FLOOR

WOODEN FLOOR

SINGLE WOODEN FLOOR

This type is useful only for spans upto 12'. When the span exceeds this, the wooden joists which are ordinarily used are uneconomical, unless they are given additional support. Double floors are generally constructed when the span is over 12'.

The floor consists of beams, generally of wood, spanning along the width of rooms and called bridging joists. These are supported on wall plates and the floor boards are nailed on the top of the joists.

Wall plate. The common size used is 4½" to 3" and these are fixed along the longer walls of the rooms.

The common practice in ground floors is to fix the wall plates in an internal offset 4½" wide at the proper level of the plinth wall.

In upper floors, they are fixed in the following manner.

(a) In an internal offset 4½" wide between the walls of the different stories. This is possible only if the walls of the two stories are of different thickness.

(b) An alternative method which is suitable for any thickness

of wall is to build the wall plate into the wall. This is not very satisfactory as the joists are likely to rot. There should be a clearance of about $\frac{1}{4}$" between joist and wall to allow air circulation near the built-in timber.

(c) A third method is to support the wall plate on a corbelled course. This is suitable for only light floors of small spans, due to lack of sufficient strength for corbelled courses to bear heavy loads and the eccentric stresses produced in the wall.

In ground floors when the span to be bridged is greater than 12', the joists are supported at intervals of about 8' on wall plates fixed over "sleeper" walls constructed at required intervals. These may be solid or honey-combed. As these carry only the load of the floor their foundation and size are suitably reduced. When constructed of bricks the walls are usually 4½" to 9" thick.

Joists: Wooden beams called bridging joists are fixed at a spacing varying from 12" to 16" (centre to centre). The joints between the wall plates and joists should be fastened with suitable iron spikes. The different types of joints between them such as plain notching, cogging etc. are illustrated in the sketches. The ordinary notching weakens the joists to some extent. In the second method the small cog is grasped by the notch in the joists and facilities the spiking also.

The sizes required for the joists have to be designed or drawn from tables. A rough rule for finding the depth of joists is given below.

Depth - (span in ft./2 plus 2) inches.

The width of joists varies from 2" to 3".

Strutts. To prevent lateral buckling of joists and to reduce the vibration of the floor, struts are fixed between the joints of over 8' span. Two types of struttings described below, are in common use.

(a) Herring-bone strutting: Timber pieces 2" to 2½" wide and about 1" to 1½" thick are nailed diagonally in pairs in a line between the top and bottom edges of adjacent joists. The spacing between the lines of struts varies from 3'-9" to 6'.

(b) Solid strutting: These consist of timber pieces about 1¼" thick and about half or more of the depth of joists are fixed similarly in a line. They are held firmly by passing 3/4" to 1" diameter steel rod through all the joists and bolting their ends to tighten the struts. The ends of the struts may be screwed or nailed to the joists to hold them in position.

Trimmings. If there is a chimney breast wall or any other opening in an upper floor for a stair landing, the bridging joists have to be trimmed in front of hearth or around the opening in the floor. This is done as described below:

Two joists called trimming joists which are of the same depth as the other joists but wider, are fixed near the jambs in the case of the chimney breast wall and at suitable places for the stair landing. A rough rule usually followed is to increase the width of each trimming joist by 1/8" for every common joist supported on the trimmer.

Another joist called trimmer of the same sectional dimensions as the trimming joists is fixed between the two trimming joists about 2' in front of the hearth. The joint between the trimmer and trimming joists should be a tusk-tenon joint.

The ends of the trimmed common joists are supported on the trimmer. The joint between the two is usually a dove-tailed housed joint with the vertical side of the housed portion of the trimmed joist which is usually about half the depth of the joist, cut in the form of a dove-tail. The wood work hear the chimney is kept well away from the hearth so that they may not catch fire or get charred. . In upper

floors, the space between the trimmer and the breast wall is covered by a segmental arch called '<u>Trimmer arch</u>' supported at one end on the breast wall and the other on the trimmer. Over the arch a concrete course is laid, which is brought to the same level as the floor boards. An alternative method is to lay a suitably reinforced concrete slab of required thickness and supported as in the previous case.

<u>Floor-boards</u> - Boards of good timber 7/8" to 1½" thick and 4" to 7" wide are nailed across the joists. Wider boards are more liable to split, warp or open out at the joints due to shrinkage.

<u>Side joints of boards</u>: The joints commonly made along the length of the floor boards are described and illustrated below:-

1) <u>Plain butt joints or square edged joint</u>:- The edges of the boards are planed square and butted against each other closely and nailed down to all the joists. The defect of this type is that joints are likely to open out due to shrinkage.

2) <u>Rebated joints</u>:- A rectangular slip 5/8" is cut at the edge of each board and they are over-lapped. Over the joists a nail is driven over the lower slip of the joint, thereby fastening at first the board carrying the lower slip. The other board with the rebate is overlapped and the nail on this is driven a bit away from the rebated portion.

3) <u>Rebated and filleted joint</u>:- Rebates about 3/8" deep and 5/8" wide are cut along the edges of the boards. While joining the boards together a hard wood fillet 1¼" wide and ¾" deep is introduced into the rebated portion of the two boards joined together. The nails are driven on both sides of the joint close to it but not into it.

4) <u>Ploughed and tongued joint</u>:- Two grooves each about 3/8" deep and 5/8" wide are cut in the adjacent boards and a hard wood fillet introduced into the two grooves while joining one

boards together. The nails are driven close to the grooves but not into them.

5) Tongued and grooved joint:-A projecting tongue 1/2" wide and depth about 1/3 of that of the board is cut along the edge of one board and a groove of the same size to fit this tongue is cut in the adjacent board. The two are fitted together and nailed as in the previous case.

Head-joints of boards: Many of the joints commonly used between the ends of the floor boards are similar to those given above. Those commonly used are:-

1) Plain butt joint, details of which are given above.

2) Splayed joint: The ends of the two boards are cut slanting so that they overlap neatly with each other. The angle should be about 45°. The joint is fastened with nails driven inclined through the two ~~pieces~~ splayed ends of the boards simultaneously.

3) Rebated tongued and grooved: In this type of joint, there is a rebate as well as a tongue and groove. The nailing is done as in the ordinary tongued and grooved joint.

Ceiling.

A ceiling is necessary to cover the joists etc. of the floor so as to have a plain polished surface and to reduce the transmission of sound from floor to floor.

The ceiling consists of thin timber boards fastened below the joists.

The methods adopted to fix the ceiling are the following:

1) the ceiling adopted to fixx the ceili
1) the ceiling boards which are usually 3/4" thick and 4" to 6" wide are nailed directly to the bridging joists. The common joints used along the edges are plain butt joints, rebated or tongued and grooved joints.

Due to the vibration of the floor, deflection of the joists and shrinkage of boards, in such an arrangement the joints are likely to open out. The sound proofing is not very effective unless sound insulating materials are placed inside the ceiling.

The method is cheap and is often practised in ordinary construction work.

2) An alternative method is to make every third or fourth bridging joist deeper than the others by about 2", and fix ceiling joists spaced about under these deeper joists. The ceiling joists are usually notched partly into the bridging joists. The ceiling boards are fixed below these ceiling joists in the same manner as described previously.

3) The third method is to fix separate ceiling beams between the walls in the same direction as the bridging-joists. Ceiling joists are fixed across them at intervals and the ceiling boards fixed to the ceiling joists.

This is the best method and such floors are sufficiently sound proof. But it is very much costlier. The depth of the floor is increased and thereby head-room is reduced.

<u>Sound-proofing of wooden floors:</u>

A common method is to nail triangular or rectangular fillets 1" x 3/4" size at half depth of the bridging-joists. Sound boarding 3/4" thick is nailed over the fillets without their edges touching the joists. Over these pugging material about 2" thick is placed. The pugging material consists of a mixture of rough mortar, saw-dust, chopped straw etc. Vegetable matter should preferably be not used for this purpose as it is liable to rot. Silicate cotton also known as <u>slagwool</u>, <u>Insulite</u> which is a form of wood shavings cemented together under pressure, are some of the patent materials used for sound proofing.

<u>D O U B L E   F L O O R S</u>

When the span of the joists exceeds 12' double floors are constructed. These are suitable for widths 16' to 24'. In this case the bridging joists are supported at intervals of 6' to 8' on beams called Binners. They are fixed along the shorter dimension of the rooms. The other parts of the construction are similar to the single floor.

<u>Binders:</u> These are usually wooden beams or rolled steel joists fixed in walls at a spacing usually varying from 6' to 8', along the shorter dimension of the boom.

A cut-stone or concrete template about 9" x 18" and 4" deep or of concrete 9" x 18" and 6" deep which are suitable for spans upto 20', is imbedded in the wall as a seating for the binders to rest. If the binders are of timber there should be a clearance of 1/4" between the wall surfaces and the binder for air circulation. As far as possible, binders should not rest directly over the door or window opening and too close to them, as these beams transfer heavy, concentrated loads to the walls. The ends of wooden binders should be firmly fixed with iron bolts as discussed previously. For long spans it is cheaper and stronger to use roll steel joists as binders. There is considerable saving in the head-room when R.S.Js. are used.

<u>Joists:</u> These are fixed over the binders and are similar in type, size etc. as in the single floor.

The joints between the binder and joists are described below:-

1) <u>Plain notching:</u> Notches about 3/4" to 1" depth are cut in the joists only and fixed over the binder. This method weakens the joists to some extent and allowance has to be made for this in design.

2) <u>Double notching:</u> In this case half the required depth of the notching is cut in each of the members. This is advantageous in this respect that both the members grip each other firmly and there will be no movement in either direction. At the same time, as far as possible, wooden binders of long span should not be notched.

3) <u>Cogging:</u> In this type, two notches of about 1" depth are cut in the binder leaving a portion slightly wider than 1/3 the width of the binder known as cog in the middle, to be grasped by the notch of the same size cut in the joists. In some respects this is a better method.

The other parts like floor boards, ceilings etc. are fixed as described in single floor.

STAIRS

Purpose: Stairs are constructed in multi-storied buildings for acess to the different floors, as well for use as fire escapes etc. in times of emergency.

Materials used in construction:

Materials commonly used for the construction of stairs are timber, brick, stone, reinforced concrete or steel. Of these timber is one of the best materials which can be treated very artistically to produce a stair of very pleasing design and appearance. Therefore, where appearance is of great importance a timber stair should be preferred. However, timber stairs are liable to catch fire easily and becomes a danger in such emergencies. It is also more noisy than other types.

The next best materials for pleasing designs are reinforced concrete and steel. Where appearance is not much of a factor, stone and bricks are suitable materials for construction of stairs.

Definition of terms:

Stairs: Stairs are steps arranged in series between successive floors.

Staircase: Is the apartment in which the stairs are situated.

Tread is the horizontal portion of a step.

Riser is the vertical portion of a step.

Rise is the vertical distance between the upper surfaces of two successive treads.

Going is the horizontal distance between two successive risers.

Flier is an ordinary step, rectangular in plan.

Winder is a step used for changing the direction of a stair. They are usually triangular in plan and are located between two flights.

Kite-winder is the central winder.

Flight is a series of steps between landings.

Landing is the flat platform between two flights.

Half-space landing - is a landing which stretches across two flights of steps or across the whole stair.

Quarter-space landing: Is a landing which stretches across one flight only.

Nosing is the portion of a step which projects beyond the face of a riser. It is usually rounded off at the end.

Line of nosing is an imaginary line joining the nosings of all steps of the same flight.

Newels are posts used at the junctions of two flights or between a flight and a landing or at the foot of a stair.

Types of stairs.

1) Straight stair: In this type all steps lead in the same direction. It consists of one, or about two flights with a landing between the two.

This type is usually used only in unimportant locations and as stairs for fire escapes etc.

2) Dog-legged stair: In this, succeeding flights proceed in opposite directions. The outer edge of the lower flight is directly below the outer edge of the flight above. Between the two mains flights there may be -

(a) a half space landing, (b) a quarter space landing and a set of winders or (c) winders only without any landing.

This type is useful for small stair-cases in ordinary residential buildings.

3) Quarter-turn stairs: This is the type in which there are only two flights at right angles to each other. Between these two flights there may be a series of winders or a quarter space landing.

4) Open Newel stairs: In this type there is a space called well between the first and last flights.

Between the first and last flights there may be:

(a) One landing only

(b) two quarter-space landings with a small flight between them

(c) Two sets of winders in continuation of the flights, with

a landing of the same length as the width of the well. This is a type which is used for important stairs of considerable size.

5) Geometrical stairs: In this type the end of the well wall is curved. Winders are used between the two main flights. Due to the curve in the end of the well the winders need not be triangular in shape but can be made with a certain width at their outer ends, which is more convenient to use, than the triangular shaped steps.

Location of stair-case and stairs:

While designing a building special attention should be paid to the distribution and location of the different stairs required in it, so that the few stairs provided in the ordinary residential buildings are located in the most useful and convenient manner. Some of the general principles to be followed are given below:

1) In residences a stair-case should be reasonably near the front entrance for convenience. At the same time it should be sufficiently screened from it for privacy.

2) In public buildings (offices etc.) the stairs should be visible from the main entrance.

3) In residences the stairs should be reasonably near the important rooms.

4) For economy and ease of construction, lighting and ventilation, stairs are generally supported on one side on walls of the stair case.

5) All stairs and especially the more important ones should be placed in such a way that it is well lighted during day-time without the aid of artificial lights.

Design of stairs:

Width of stairs: The minimum width of each flight should be sufficient for two people to cross each other conveniently. The absolute minimum which should be used only for unimportant stairs is 2'-9". For better convenience, the width should

ordinarily be 3' to 4'. For all important stairs the width should be about 4' to 5'.

Head room: No portion of a landing or a floor or other similar obstructions should come with in a vertical distance of 7' of the line of nosings of any flight.

Number of steps in a flight: As far as possible, a flight should not contain more than 10 steps. This maximum limit is sometimes increased to 12 or 15 in the case of unimportant stairs. As far as possible, a flight should not contain lesser than three steps.

A long flight is tiring for old people to ascend.

Winders should be avoided as far as possible, as they have little or no width at all on the outer edge, and they are dangerous if carelessly trod upon.

Rules for determining tread and rise.

The rise should be between 5" and 8".

Going should be between 8" to 13".

The two well known rules for determining tread and rise are given below.

a) Tread in inches multiplied by rise in inches should be approximately equal to 66.

e.g. 11" tread and 6" rise.

10" tread and 6½" rise.

b) Twice the rise in inches plus the tread in inches should be approximately equal to 24.

e.g. 12" tread and 6" rise.

10" tread and 7" rise.

While designing, fix one dimension of the step i.e., either the tread or the rise, and determine the other.

The difference in height between the floors divided by the rise will give the total number of risers necessary.

Treads will be one less in number.

Construction of stairs.

A brief description of the construction of a timber

dog-legged stair is given below.

The open newal type is a modification of this.

The angle ofpitch of the stairs i.e., the angle of inclination of the line of nosings to the horizontal should be determined first, from the rise and the going.

A pitch board should be made of timber to mark the tread and the rise. The positions in which the treads and the risers are fixed on the strings are marked out carefully with the help of the pitch board and notched to receive the ends of treads and risers and the wedges to tighten them in position.

<u>Strings:</u> These are timber boards 1½" to 2½" thick and about 9" to 12" depth. The actual depth will depend on the ratio of the rise and going, the type of the soffit etc. These are fixed along the two edges of the flight and are also known as stringer, string boards etc.

A close or housed string is one which has both its top and bottom edges parallel to the line of nosings of the flight. A cut or open string is one which has its top edge cut in a serrated manner to accommodat e the treads and risers. For stairs of small width and length one wall string which is usually fixed to the wall and an outer string would be sufficient. When the width exceeds much above 3', additional strings called rough strings or rough bearers of carriage are fixed below the stair by means of rough brackets, to prevent bending. One or more, of size about 4" x 2" to 4½" x 3" would be sufficient for ordinary stairs. The soffit i.e., the bottom portion of the flight is covered by fixing timber boards or a plastered ceiling to the rough strings. Otherwise cupboards can be accommodated conveniently under the stairs for storage space.

The wall strings are fixed to the wall by nailing them to a number of wooden plugs of well seasoned timber built into the wall. An alternative method is to bolt them to iron bolts imbedded in concrete blocks cast in the wall in the

required positions. One end of the outer strings is fixed to the newel posts by double haunched tenon joints. The lower end of the outer string of the bottom flight is fixed to a wooden block imbedded in the floor or tenoned into a newel post which is fixed in the floor. If the newel is of the type that is supported at the bottom on floor, the method of fixing is described above. In the case of floating newels the top end of the string is fixed to the beam carrying the landing.

The top end of rough strings are supported on a pitching piece of about 4" x 3" to 6" x 2" size. They are sometimes attached directly on the trimmer. One end of the pitching piece is built into the wall and the other end tenoned into the newel.

Treads. The treads which are 1" to 1¼" thick and the risers about 7/8" to 1" thick are fixed to the strings by housing or trenching their ends to a depth of ½" to ¾" into the strings. The bottom edge of the grooves are made slightly tapering and small wooden wedges are driven in to tighten this joint. In addition these joints should be strengthened by screws. The first and last step and one or two of the middle steps are usually tenoned into the strings with three tenons in each piece to frame the strings, treads and risens together. The treads are supported on rough strings with rough brackets which are timber boards of about 6" width and 1" thickness. These are screwed to the side of the rough strings and to the treads.

The joints between the tread and the riser are tongued and grooved. The tongue is cut in the riser and the groove in the tread. This connection is often further strengthened by nailing a few triangle shaped blocks on the underside of the joint.

Winders. These are the triangular or wedge shaped steps situated between two adjacent flights to change direction between the connected flights.

They are supported on cantilever beams built into the walls when floating newels are fixed at the junction of the flight. The edges of the treads and risers have to be screwed on to their upper and vertical faces respectively and their levels, positions and directions have to be such that this purpose can be accomplished. The timber used for the purpose should be durable, well-seasoned, hard-wood and the beams should not sag due to warping, shrinkage or improper bond with the masonry. Their outer edges are tenoned into the newel-posts. An alternative method of supporting winders in case the newels are fixed to the floor at the bottom, is to fix wall strings for the winder flights also and provide separate beams of about 3" x 2" size which is suitable for a row stairs, to which the edges of adjacent treads and risers are joined.

At the top and bottom of the winder flights bigger bearer beams (4" x 3") should be placed and the lower ends of the rough bearers should be fixed to them by suitable notched points. In addition they have to support the risers of the first and last winders.

The ends of bearers should be fixed to the wall-strings and newel-posts by housed tenon-joints.

A third method is to fix rises thick enough to serve as cantilever beams to support the winders in the required positions and screw on the edges of the treads to these risers. Their outer ends should be tenoned into the newel.

Newels. These are posts fixed at the outer junction between two flights and at the top and bottom of end flights in a stairs. One end of the hand-rails, outer strings and trimmers are joined to it. They are usually square, hexagonal, octagonal or round in cross-section and the top ends called caps carved to artistic shapes for the sake of appearance.

Newels are of two types. Those with their bottom ends fixed into the floor below by, building into concrete or bolting to floor beams, is known as "fixed newels" and those which end at the level of the soffit of the stair are known as "floating newels". The fixed newels affords better support to the flights and prevents sagging of the beams which otherwise have to be cantilevers. On the other hand floating newels adds to the weight to be supported by the cantilevers or trimmers.

Landings. The flat platforms between flights are called landings.

The width of all landings should be equal to that of the flights and length vary according to the type of the landing.

The construction is in most cases similar to wooden floors. Beams called trimmers are fixed into the wall and to the newel post. The landing joists are supported as ordinary beams between the walls and the trimmer in a manner similar to trimmings in wooden floors. The floor boards are fixed to the joists the top levels of which should be adjusted to suit this purpose.

Balustrade: This is the frame-work fixed along the outer edges of the flight for protection.

The framework consists of posts called "balusters" and a sloping rail called "hand-rail". The alternative to this is to fix frames cast with bronze or iron.

The balusters of wood and usually round of about $1\frac{1}{2}$" diameter or square of about $1\frac{1}{4}$" side. Carved balusters of bigger sectional areas are at times used in wide stairs. Their lower ends are either housed or jaggled into the top faces of the outer strings or joggled to the treads or halved and screwed on to the outer or inner faces of the string. The top ends are similarly joined to the bottom faces of the hand rail.

The spacing of the balusters should be 3" to 4" and height about 3'.

The hand-rail is in most cases made of wood moulded to various smooth curved shapes. Their ends are tenoned into the newels.

D O O R S   A N D   W I N D O W S

Doors are meant for communication from the outside to the interior apartments of buildings and for inter-communication between the different portions within the building. The former type of doors are called "External doors" and the latter "Internal doors". Their location size and type have therefore to be decided primarily by these necessities. The secondary purposes are that of ventilation and light.

Location: Important external doors have to be located in such a manner that they lead into the main rooms and are at the same time protected from the weather, so that they can be kept open during stormy weather. The positions of internal doors should be suitable for moving from room to roor conveniently. For maintaining continuous movement of air in the interior portions of buildings, there should be openings such as doors and windows in opposite walls.

Frames. Door frames are the outer frame-work which is built into the walls for hinging the doors.

A door frame consists of three or four members forming a rectangular frame-work. The two vertical pieces are called posts the top horizontal piece, the head, and the bottom member is called the sill. The horizontal member project beyond the verticals for a length of about 6" and that portion is usually called the 'horns'. These help to build the frame into the masonry more rigidly. In addition hold-fasts which are made of flat-iron about 1/4" thick $1\frac{1}{4}$" to 2" wide and 9" to 12" long are bolted to the posts. One ends of the hold fast is bent to a length of about $1\frac{1}{2}$" to bolt it to the frame and the other end is bent similarly to secure the hold fast in the masonry joint. Three such hold fasts have to be fixed on each post and the bolt heads of the holdfasts should be counter-sunk into the posts and stopped with wood plugs.

All the members are of 4" to 5" wide and 3" to 3½" thick in cross-section. A rebate 1/2" to 5/8" wide is cut along one face of the frame to receive the door when shut. The outer edges should be chamfered or moulded. For facility of washing and cleaning the floor, at times the sill is omitted from the frame. But such a frame is unsuitable for external doors, due to the likelihood of rain water flowing through the inevitable clearance between the threshold and the door. The posts should in such types be built into the floor with the help of iron dowel-bars about 3/4" diameter and 9" to 12" long. An alternative method is to fix a long iron bolt 3/4" to 1" diameter between the feet of the posts and build it into the floor. Special precuations have to be taken to prevent the rotting of the built in portion of the posts. Protection coatings should be applied on all faces of the frame which in contact with masonry. Creosote or tar is usually preferred for this purpose. If the door frames are to be painted the priming coat should be applied before building in. Otherwise they should be suitably protected from weather during the initial stages of construction.

The common procedure for building in the frames is to place them truly vertical in the required position when the masonry is constructed to the plinth stage. They are temporarily supported by inclined struts. Proper care should be taken while forming the jambs of the door so that no ugly crevices are left between the wall and the jambs do not absorb much moisture. The hold fasts should be set correctly in the mortar joints.

The position of the frame in relation to the thickness of the walls will depend on the direction in which the door opens. The principle object should be to minimise the length of obstruction caused in the floorspace by the open door.

Types of doors:

Doors usually consists of one or two shutters or leaves which are hinged to the frame. Accordingly they are said to be single hung or double hung doors.

According to the type of construction of the door they are classified as follows:-

1) Ledged door.
2) Ledged and braced-door.
3) Framed and ledged door.
4) Framed, ledged and braced door.
5) Framed and panelled door.
6) Half glazed half panelled door.
7) Wire gauze doors.

The details of construction of the various types mentioned above are discussed below. Minor modifications are at times made for the sake of appearance, light and ventilation.

1) Ledged-door. This is ordinarily a single hung door which is fixed in important locations and for out-houses and other buildings where appearance is not of importance. It consists of battens 3/4" thick and 4" to 7" wide screwed on to three ledges of about 6" x $1\frac{1}{4}$" size. The shrinkage and resulting opening of joints is lesser in the case of narrow battens. The sizes of the ledges may differ in size, the top one being 4" to 5" x $1\frac{1}{4}$" and those in the middle and bottom of 6" to 7" x $1\frac{1}{4}$" in size.

The width of the door varies from 2' to 2'-9" and height 6' to 6'-6". Doors wider than this are liable to sag and loose shape.

In unimportant locations such as in out-houses and courtyards the door is fixed with country hinges made of flat iron of 1/4" or lesser thickness, hung in an L shaped hook of about 1" diameter, which is built into the jamb. The length of the hinge may vary from 12" to 18" depending on the weight of the door. For heavy doors spikes

would be necessary to fix the hinge to the ledge and screws for light ones. The alternative is to hinge the door in a frame built into the wall.

The defect of this door is that it sags and refuses to fit into the rebate in the frame and damage the floor when it is not fixed in a frame.

2) Ledged and braced door. This is somewhat similar in construction to the previous type. The sag which may occur is minimised by two inclined braces placed between the ledges. They should slope downwards from the outer-edge towards the hinges.

Braces of 4" x 1¼" would be sufficient for ordinary doors with the top ledges of similar size. Their ends are cut into an inclined notch of about 1" depth in the ledges.

3) Framed ledged and braced doors. The framed doors are different in construction from the types described above. They are more rigid in construction and often lighter in weight. The outer frame work consists of the horizontal pieces called top-rail, middle or lock rail and bottom rail and two vertical pieces known as styles. The style carrying the hinges is called hanging style, and the other the meeting style if the door is double hung. The styled and the top rail are normally similar in size varying from about 4" x 1" to 4½" to 2". The middle and bottom rails vary in size from 7" x 1" to 9" x 2".

The top rail and the styles are joined by means of ordinary mortise and tenon joints in which the tenon is 1/3rd to 1/4th the thickness of the members and width about 1/2 to 3/4 that of the rail. The joint is secured with wood dowels or screws. The joint between styles and the other rails are double haunched tenon joints. The total width of the tenons is equal to about half that of the rails.

The middle rail is fixed in the middle of the height of door or slightly lower so as to fix the bolt, lock etc. at a

convenient height. The battens which are thinner than those of the ordinary ledged and braced door are fixed to the bottom and lock rails with screws. The battens along the edges of the frame are joined by tongue and grooved joints to the styles and the top-rail. The tongue of such joints are cut along the inner edge of the battens and not in the middle as is usually done for ordinary tongue and groove joints. The thickness of the styles and the top rail is greater than the other parts of the frame-work by the thickness of the batten which is usually not more than 1".

The joints between the edges of the battens, and other details are similar to the previous types of doors.

4) <u>Framed and battened door</u>.

This is a door somewhat similar in construction to the previous type, but lighter and cheaper in construction.

The frame-work consists of five members of the same thickness and not of varying thickness as in the former type of door. These are jointed together by single and double haunched tenons and the inner edges of the frame are chamfered or to remove sharp edges.

The battens are fixed to the frame-work by means of tongue and grooved joints. The tongue cut along the inner edges of the battens joined to the frame. Work on all sides fits into grooves of about 1/2" depth in the frame so that the outer face of the batten is flush with that of the frame. The thickness of the tongue is usually about half that of the batten.

An alternative method is to cut the groove of the joint in the middle of the thickness of the frame and the tongue in the middle of the thickness of the batten and fix the battan in the centre of the frame.

5) <u>Framed and panelled doors.</u>

This type of door consists of an outer frame work in which a panels of wood are fixed. The panels may be two,

three, four or six in number according to the size and type of the door.

a) Framed door with the two panels. The frame consist of styles, top, middle and bottom rails. They are framed together in the same manner as the former type. The size of the members for ordinary doors vary from 4" x 3/4" to 4½" x 1½" size, depending on their overall size. These are framed in the same manner as was described in the previous type. In this case the middle rail is fixed usually lower than the middle of the door height, in such a way that the top of the lock rail is at a height of about 3' from the bottom of door.

Panels. The panels are made of boards of timber, 1/2" to 7/8" thick for ordinary doors and 1-1/8" thick for very large doors with raised panels. Ordinarily the thickness of the panels should be about one third that of the frame. The panels may be 'plain' or 'raised'. The plain panels which have plain surfaces are usually of about 1/2" to 7/8" thickness and are ordinarily fixed in the frame in the middle of its thickness, by grooving in its entire thickness in a ½" deep groove cut in the frame-work. An alternative method which is generally adopted for raised panels is to fix it in such a way that the raised and the moulded face of the panel is flush with the face of the frame-work when it is sometimes termed a flush panel.

The raised panels have one plane face and the middle portion of the other outer face is raised forming a ridge in the middle. The edges of the raised portion is cut to any desired shape and often moulded. The sunk edge of the panel which is about 1/2" thick is fixed in a groove about 1/2" to 5/8" deep and in the frame. In addition, mouldings which are strips of timber 1¼" to 2" wide with one face moulded, are mailed along the edges of the panel to improve the appearance.

The size of this type of door may vary from 2' to 2' 9" which is the maximum for ordinary doors and 3' or more for double hung doors.

b) <u>Framed and panelled door with four panels</u>.

This door has four panels fixed in the framework which therefore requires an additional member style called 'munting style' in the middle. This is usually in two pieces and of the same size as other styles. Their ends are tenoned into the rails by single tenon joints.

The panels are similar to those described in the previous type.

The width may vary from :. 2'-9" to 3' or more as was mentioned previously and both single and double doors of this type are made to suit different widths.

c) <u>Framed door with six panels.</u>

This type of panalled door consists of a frame covered with six panels. In addition to the muntings style a rail also is added near the top rail. This is usually known as the frieze rail and is of the same size as the munting style. For the sake of appearance this is usually fixed in such a way that the two top panels are square in shape.

Thesdx doors are generally single hung with a maximum width of 2'-9".

6) <u>Half glazed half panelled door</u>.

Doors glazed with glass panels are usually used in locations where it is necessary to admit light even when the doors remains shut. The portion above the lock rail is usually glazed and the lower portion is panelled with wood.

The construction is similar to the previous types of framed doors in several respects. Due to the necessity of fixing several glass panels thin wooden bars called 'glazing bars or sash bars are framed together to support them. They are about $1\frac{1}{4}$" wide and of same thickness as the door and are

fixed by tenoned and scribed joints. The horizontal bars are continuous and the verticals in pieces.

For increasing the area of the glazing, the styles are reduced in width in the glazed portion of the door. These are called 'diminished styles'. A typical reduction in width is 4½" to 3" and is done by a slanting cut on the style on which the lock rail is fixed by a double tenon joint.

Glazing. The glass panels are usually rectangular in shape. A suitable relative dimensions of the sides of the glass pane can be found by the rule that the length or height should be equal to the hypotenuse of a square formed on the width as sides.

Typical dimensions of panels are:

The glass panels are fixed to the bars by means of small strips of wood called glazing bead, nailed or screwed behind the glass which is fixed in a 1/4" x 5/8" rebate cut in the bars. An alternative method is to fix it with glaziers putty in a similar rebate.

The width of glazed doors vary from 2' to 2'-9" in the case of single hung door and 3' or more for double doors.

7) Fly-proof wire-gauze doors:

This is similar in construction and size as the two or three panelled doors. Instead of wooden panels wire gauze of suitable gauge is fixed in the same way as glass panels.

It is particularly useful as a fly-proof door for kitchens, hospitals, bathrooms etc.

Such doors should preferably be provided with some device or other to shut automatically. Special spring and skew hinges are available for this purpose.

8) Plywood doors:

The framed plywood doors are made of an inner core of inferior timber covered with a facing of plywood. The core is made up of a frame similar to three panelled doors.

Several more smaller horizontal rails are added as a backing to the plywood. The wood used for the frame work is treated with preservatives. The plywood sheets are glued to the frame under pressure.

WINDOWS

Windows are necessary in buildings to admit light and air and to keep a steady stream of fresh air passing through the interior portions of the building.

Location: For admitting sufficient amount of fresh air and light, windows are most necessary on the exterior walls and to a lesser extent only in the interior partition walls. Several types of windows have been evolved to suit different locations and purpose and details of a few among them are given below.

Ordinary windows are fixed usually at a height of 2'-9" to 3' from the floor level. Windows with fixed sashes only are fixed at heights of 4' to 5' in bath rooms and other locations where primacy is necessary. Clerestory windows are usually located near the roof level of exterior walls for light and air.

Size: According to some model bye-laws and other specifications the minimum area of windows should be one tenth of the floor space. But actually it has to be about one fourth. This would be necessary for rooms which require a good deal of light and ventilation. One fifth to one sixth would be suitable proportions for the important rooms of residences, offices and buildings of a similar nature.

Window frames: Ordinary window frames are similar in construction to that of doors, consisting of two verticals called posts or jambs and horizontal members called head and sill. If the window consists of two sashers meeting in the centre at times are additional vertical member called 'mullion' is fixed in the centre. A third horizontal member called

'transome' is added if the size of the frame exceeds ordinary dimensions. Special attention has to be bestowed for bedding of frames of windows situated in the exterior walls, in the masonry. The most important among them is the prevention of rain water finding its way to the interior. For this purpose window frames should be fixed a short distance inwards from the outer face of the wall and all external windows should open outwards, and the sills of windows should be carefully constructed as a damp-proof course. In addition plastering or pointing of the jambs should receive special attention. A semi-circular groove also is usually cut along the underside of the sill as a throating. The size of the members of ordinary windows vary 4" by 2½" to 5" x 3".

The frame should be checked to receive the plaster.

<u>Types of windows</u>.

Windows are fixed in different ways depending on the purpose, for which they are meant and the type of the sash. The ordinary windows are classified accordingly as given below.

1. Solid framed window with fixed sash
2. Framed window with centre hung sash.
3. Framed window with vertically hung sash.

1. <u>Solid framed windows with fixed sash</u>.

These windows are fixed to the ordinary solid frames which are similar in construction to that of a door. No hinges are provided for the sash and it is not possible to move it in any direction, as they are meant for lighting purposes only.

<u>Sashes.</u> These are glazed windows which are fixed or hung in the frame.

The construction consists of a frame work in which the glazing bars or sash bars are fixed to receive the glass panels. The frame work of the sash consists of ~~this~~ four pieces called styles and rails. The thickness of this

vary from $1\frac{1}{4}$" to $2\frac{1}{2}$". Unlike the door the width of all the members are usually the same and may vary from 3" to 4". To increase the area of glass the thicker frames may be made of lesser width of 2". At times the bottom rail has a width greater than the other parts. Joints and other details of construction are similar to the door. All the joints are ordinary tenon joints.

2. Framed window with centre hung sash.

These windows are pivoted in the middle of the height so that it can reolve about it in one direction through an angle of 90°. For this purpose the posts of the frame are rebated suitably so that the window fits into the rebated space and no water leaks past. Suitable bolts are fixed at the top of the sash to lock it in the shut position. The pivet is usually fixed slightly displaced above the centre so that the window may close automatically due to the eccentricity of the hinge when the cords holding it in the horizontal position is released.

3. Framed window with vertically hung sash.

These are at times known as casements or casement windows and are the ordinary glazed windows hinged to open outwards.

The sashes are constructed in the same manner as the sashes already described. The height is usually more than the width and each sash is hinged to the frame by means of two hinges sunk into the wood.

The sizes of the ordinary casement window varies from a width of 2'-6" to 4' and a height of 3'-6" to 5', although windows with one sash have lesser widths. Wide casement windows with more than two glazed sashes are made when greater area of windows are necessary on exterior walls. The overall widths of these are usually greater than their heights. Additional posts are fixed in the frame to support the sills and the sizes of the various pieces of the frame have to be greater than those of the ordinary windows. The overall

width vary from about 5' to 7' and height 3'-6" to 5'.

The details of the construction of the frames of these windows are somewhat similar to the ordinary casement windows, but the sizes of the frame members are bigger.

The common arrangement is to hinge a single sash on the edges of the window and two sashes together in the middle. In the wider windows all the three portions may have double sashes.

The construction of this sash is similar to the other glazed windows, but, ordinarily its length is more than the height although variations from this shape are adopted for special purposes.

<u>Bay-windows:</u> These are also wide windows with several fixed and movable sashes and located on outter walls. The special purpose for which they are meant is for increased ventilation and light as well as for improving external appearance. The area of the glazing is increased by extending outwards the walls accommodating the window by junctions at angles of 120° and the sashes are fixed in these projecting walls.

The sashes, frames and other portions of the window are similar in construction to the former type of casements.

<u>Clerestory windows:</u> Small fixed or pivotted sashes which swing on central pivots, fixed near the roof level of outer-walls are known as clerestory windows.

They are usually about 2' to 2'-6" wide and 1' to 1'-6" high although square shape is not uncommon.

Ordinarily clerestory windows are fixed about 1' to 1'-6" below the bottom-most level of the roof or floor. They are meant specially for movement of air and light in the upper portions of the space in rooms.

The constructional details of similar sashes have already been described.

Louvred window: These are windows made entirely of wood and hinged usually on the outside of frames to open outwards, together with a glazed sash on the inner side to open inwards. They are meant mainly as a screen for the inner glazed sash and for ventilation.

The frame-work of the sash is similar to the other types. Within this louvres which are wood battens about 3/8" to 1/4" thick are fixed sloping at an angle of about 45° or more in grooves cut in the stiles, so that direct sight is not possible through the louvers. The widths of the louvers will vary according to the thickness of the stiles and the angles at which they are set in the frame.

Dormer is a window fixed on sloping roofs to light attics and other portions of the buildings where additional light is necessary.

Window sill courses. These include all the special courses constructed at the sills of openings in which the window frame is fixed.

The courses usually consist of damp resisting and at the same time are also ornamental courses. The sills of exterior windows are subjected to considerable dampness in wet weather and special courses of damp-proof materials are necessary in such locations.

The sill courses of windows are constructed of shaped stones usually terminating as a drip course with a sloping top surface called 'weathering' and a groove called 'throat' on the underside. This portion projects about 2" beyond the face of the wall so as to drain off the rain water clear of the wall. The stones forming the course are set in special cement mortar with weather proof shaped joints. They have to be thorough courses if the frame is fixed towards the interior face of the wall. Otherwise the stone sill courses cover only part of the thickness of the wall at the sill.

Iron water-bases are at times fixed in the course to prevent seepage of water along the surface.

An alternative method is to lay moulded cement concrete courses above the brick-work to cover the sill.

Sun-shade. Windows located on exterior walls have often to be protected from weather by a roof-like covering called sun-shade.

Sun-shades should be about 2' wide and 6" to 12" longer than the width of the window.

They are made of reinforced concrete slabs or of a framed structure made of wood or iron and covered with tiles, galvanised iron or asbestos sheets.

Sun-shades of concrete are either cast in site as a cantilever slab built into the entire thickness of the wall or cast earlier and fixed in position at the appropriate stage of construction.

It consists of either a plain reinforced slab or a slab supported by concrete beams along the two edges, in which case the reinforcements of the slab can be reduced considerably. An alternative method is to fix concrete brackets along the two edges.

Sun-shades covered with other roofing materials are usually supported on two brackets of iron or wood, fixed on the two edges, between which timber scantlings are fixed to support the roofing materials.

The level of the edge of the sunshade should be the same or a few inches above the top of the window frame.

Hinges: The hinges commonly used for doors and windows are mentioned below.

Usually each door is fixed with three and windows with two hinges. The hinge should be sunk completely into the wood and fixed with screws long enough to hold the door or window in position. The screws used should be of suitable size to

sink their heads into the bevelled edge of the holes in the hinge.

Strap-hinge. This consists of wrought iron strap about 1/4" thick. One end of the strap is bent to form an eye. This is hung in a hook which is built into the wall.

Butt-hinge. This is the most common type, consisting of two flasps joined together by a revolving pin and knuckle joint.

The hinge is available in different sizes to suit various sizes of doors and windows.

Skew butt hinge. In this type the surfaces of contact of the knuckle joint is helical in shape, making the door rise slightly when it is opened. This is helpful in clearing door-mats, carpets etc. and some types of this hinge makes the doors shut by itself unless they are stayed.

Bolts and other fixtures.

Tower-bolts.- are available in different sizes of two parts namely the bolts and staples. The bolts are fixed to the door and staples on the frame.

Barret bolts - are more or less similar in construction to tower bolts.

Flush bolts - are flatter in shape and are used when fittings which project out too much are objectionable.

Lintels

Lintels are the beams supporting the masonry above the openings in which the doors and windows are fixed.

They are variably made of wood, stone, reinforced concrete or reinforced brick-work. If good timber is readily available, wood lintels are suitable for ordinary construction work. But care should be taken to avoid shrinkage, cracks, warping etc. of the wood, which affects the external appearance.

Reinforced concrete lintels are better adopted as beams built into the masonry around the beam and are

stronger and more durable. But they are more difficult to construct and costlier than wood lintels.

Reinforced brick lintels are cheaper than reinforced concrete lintels and suitable for small spans over ordinary doors and windows.

Wood lintels. Beams of well seasoned durable strong wood are built into the masonry for a length of at least 4" to 6". The width of the beam should be same as the thickness of the wall and the depth should be sufficient to carry the load of the portion of the masonary forming an equilateral triangle over the span, without any appreciable bending. If single beam of suitable width is unavailable, two sections bolted together may be used. The usual precautions against rotting of the portions built into and in contact with masonary should be taken.

To improve the appearance of the exposed faces, moulded pieces covering the two faces of the lintels should be nailed.

Fire-places

Fire-places are necessary forburning some type of solid fuel or other for heating up the air inside the rooms during cold weather and remove the smoke produced through chimneys discharging into the atmosphere above the roof.

The requirements of an efficient fire-place are the following:-

1) To get the initial and later a steady combustion of the fuel.

2) To maintain a steady draought of smoke up the chimney so that no smoke enters the room and fouls the air.

3) To reflect the maximum amount of heat from the hearth into the room.

To achieve the objects given above the following points require special attention.

a) The combustion chamber should be designed properly.

b) To find the size of the fire-place opening to suit the size of the room and to make the sectional area of the flue proportionate to the fire-place opening.

c) To design the smoke chamber and throat properly.

Location of fire-place. It is not possible to lay down hard and fast rules for the proper location of a fire-place. A fire-place should in general be located to obtain the maximum radiation of heat into the room as well as for facilities for its construction.

People sitting in front of the fire place should not be subjected to cross-draught of cold air.

To avoid loss of heat fire-places and flues should not be built on exposed exterior walls which is subjected to rapid cooling.

For facility of constructing the flues and chimneys it is better to locate the fire-places in adjacent rooms back to back on the same wall so that a common stock can accommodate all the flues.

Size of hearths and fire-place openings.

The size of the fire-place opening should be proportional to the size of the room. For about 300 sft. of floor space an opening 30" x 36" is found to be sufficient. For rooms of bigger sizes the opening may be increased to about 36" x 42". The minimum width should be about 24" to 30" and height about 30".

The depth of the hearth should be as small as is possible for radiation of heat. At the same time if it is too shallow, it is likely to eject smoke into the room. The possible depth is also governed by the extent up to which the jambs can project into the room and the thickness of the wall on which the hearth is built.

The depth of ordinary fire-places vary from 12" to 18".

Combustion chamber: This is the lower portion of the fire-place in which the fire is burnt.

For radiation of heat into the room, the sides of this chamber should be splayed towards the back at an angle of 45° to 60° and the walls should lean forward at a batten of about 1 in 3 to 1 in 4. The slope should not be more than 30°.

The outer surfaces of the hearth should be lined with fire-brick and the opening supported on suitable flat or segmental arches.

Throat. The constricted passage situated between the top portion of the hearth and the beginning of the flue is called the throat. This constricted portion accelerates the flow of hot smoke up the flue.

Depending on the shape of the hearth and the flue the throat may be rectangular, square or circular.

Smoke chamber: The throat widen out to form a portion at the bottom of the flue, known as the smoke chamber. The widening out is done by horizontal off-set in the wall which is known as the smoke-shelf. This serves as a partial obstruction to the passage of any cold air down the flue and deflects it upwards through the current of hot smoke.

Flue is the hollow pipe-like passage made to convey the smoke upwards and discharge it into the atmosphere. The top portion of the flue which projects above the roof is usually called the chimney stack.

The shape of the flue may be square, rectangular or circular and the surface should be lined with fire-bricks and smoothly plastered with fire-resisting plaster or fire-clay.

A rectangular flue should be varying in size from 6" x 9" to 9" x 14" or about 6" to 12" diameter.

A rough rule for the flue size is that it should be about 1/10th to 1/12th the area of opening of the fire-place.

Flues of adjacent fire-places should not be connected together to a common flue as this is likely to discharge

smoke from a lighted fire-place through an unlighted cold fire-place adjoining it.

Chimney stack. The flue is carried high above the roof through chimney stacks. The stacks are extensions of the chimney breast walls beyond the level of the roof. As the width of the breast wall is more than that required to enclose the flue, it is usually reduced above the ceiling levels by racking or fewer number of off-sets. The top of the stack should project at least 5' beyond the highest point of the roof of the building to prevent downward blowing of smoke emanating from the outlet.

At the top of the stack smoke outlets are provided for passage of smoke from the flue. The holes are usually equally distributed on all the surrounding walls of the stack and are rectangular or square in shape. The top and bottom surfaces of these holes should slope downwards from the flue so as to prevent blowing in of rain-water.

The total area of the smoke outlets should be equal to the sectional area of the flue, if not slightly more than that.

The top of the flue should be covered with cement concrete or stone slabs. The edges of the slabs should be weathered and throated.

A better alternative method which provides screen walls all around the smoke outlets as a protection against heavy wind blowing smoke down the flue is shown by means of sketches. Such a construction requires periodical cleaning to remove bird-nests and other obstructions to smoke which may find its way into the smoke outlets.

Cooking Range

The raised platform on which the ovens for cooking are built is usually known as the cooking range.

The construction of the hearth and the portions of the range to discharge the smoke are in several respects similar

to the fire place already described.

Hearth. This is the portion of the range which accommodates the ovens. It is usually situated on a raised platform constructed ofbricks or stone. The height of the hearth may vary from 2' to about 2'-6" and rarely upto 3'.

This flat platform is usually supported a lintel or on segmental or semi-circular arches built near the floor-level in the breast-wall of the hearth. The space underneath the arch serves as a storage space for fuel. The width of the hearth has to vary according to the number of ovens in it. Ordinarily the width should not be lesser than 3' to accommodate two or three ovens. 4' would be a more convenient minimum width. A hearth of average dimensions should have a width of about 5'.

The depth of the hearth depends on the extent up to which the jambs of the breast wall can conveniently project into the room and the width of the hearth. A wide hearth should be deep enough to prevent smoking into the kitchen. The depth ordinarily varies from 1'-6" to 2'-6". Bigger hearths may be slightly deeper than this.

The ovens which are usually circular in shape are built about 12" apart with suitable provision to collect and clear off the ash. The opening of the hearth is supported by a suitable segmental or semi-circular arch or reinforced concrete lintel. The crown of the arch should be about 5' to 6' above the floor-level. An arch taller than this is often the cause of smoking hearths.

Flue. The side walls alone or all the walls above the hearth slope to form a narrow passage for smoke, called the flue. The internal dimensions of the flues for cooking ranges have to be considerably larger than the flue of fire-places in rooms, as they have to discharge larger volume of smoke. 18" to 24" width and 12" depth or similar apppropriate diameters are nothing unusual for the flues of cooking ranges.

The thickness of the walls around the flue should be at least 9" and the width of the breast wall is reduced by recking or off-sets to the required extent to form the stack.

<u>Stack</u>. This is similar in construction to the fire-place described before.